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Electrical Engineering

JULY, 1896.

UNWARRANTED INTERFERENCE OF THE UNITED STATES IN THE BANKING BUSINESS.

BY AUSTIN W. WRIGHT.

The people of the United States are confronted with a most alarming financial situation. Regardless of their political affiliations or whatever may be their economic belief, all are agreed that the present state of affairs is more than grave and that the near future will probably bring forth developments more desperately alarming than anything yet experienced. Most people past middle age still bear the financial scars of the panic of 1873-8, nor is the depression of 1884 unforgotten. There is a keen remembrance of 1890, and the still open wounds caused by the panic of 1893 are everywhere present and therefore vividly in the minds of all. Thus to say that everybody is in a disturbed state of mind, nay more, that there is a consuming fear abroad in the land in relation to the financial situation is but a simple statement of the truth.

The "gold bug," the "silverite," and that economic hermaphrodite who calls himself a "bimetalist," each and all agree as to the gravity of the situation. But when it comes to a review of the causes which have produced our money troubles, or the corrective remedies that should be applied as a cure therefor, there is such a wide and radical difference of opinion that few are able to even discuss the problem without descending to the use of vituperative personalities; in their heat they forget that impugning personal motives is not argument, and that no controversy can be settled by vituperative denunciation. If there ever was a time when calm, dispassionate argument only should be used, it is right now. What is it that, without exception, we all most

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want? Good money, is it not? With the further assurance that we shall continue to have good money. The crux of the question is, How are we to get it? Here is where the doctors disagree, and the disagreement is wholly due to an entire misconception as to what constitutes money and the value thereof, and of the proper functions of government in relation thereto.

Most people confound standard with value. They also think that the power of the government to name a standard of coinage and to fix the mint price of the coin in relation to the bullion of which it is composed extends beyond that proper function, and that therefore the government can fix the value of coins composed of different metals in relation to each other. Value, in a primary sense, is simply *desire* or *esteem*. Before value can be brought into economics it must become manifest by exchange. Something must be exchanged for something else. It is evident that no exchange can take place without the concurrence of at least two people. "When, however, two persons each *desire* or *demand* to obtain the product of the other, and when they agree to exchange their respective products, each product may be considered as the *measure* of the desire of the owner to obtain possession of the product of the other. The two products, therefore, reciprocally measure the *desire* of their possessors to obtain the product of the other; and when these persons have agreed upon the *quantities* of their products which are to be exchanged, the two products are said to be of equal value. Each product is the value, or the demand for the other, and this is the only kind of *value* with which economics is concerned." *

Price is the expression of value; it is not separate in exchange. A exchanged for B, each becomes the price of the other; B becomes the price of A expressed in terms of B, and vice versa.

The value of a thing is always something external to itself; the expression of value is unthinkably disconnected from or disassociated with the idea that the commodity thought of can be exchanged for some other commodity. A single commodity cannot have value by itself any more than it can have equality. So when it is said of any commodity that it has value, it must be asked: "Value in what?" This applies to money as forcefully and is as true of money as surely as it is of anything else.

Money is simply a commodity that is generally recognized as

* Henry Dunning Macleod: "Elements of Economics." Page 225, Vol. I.

a universal equivalent, and its degree of goodness or efficiency consists in the unanimity of the recognition of the fitness of the commodity used as money to perform the essential functions of money. Many commodities have been used as money and they have remained in use as long as they met the essential requirements of money among the people where used or until some other commodity appeared, the fitness of which commended itself to the intelligence as being superior to the commodity then being used. As people have advanced in discriminating intelligence they have discarded inferior commodities and adopted in place thereof something that was superior; these changes kept taking place until finally gold and silver became the commodities that were recognized by the people of most countries as being the best for use as money. Sociological transition is constant. Change is the natural order of things and changes come about naturally and are therefore effected easily if the natural process is allowed to go on undisturbed; troublous friction ensues only when there is obstructive governmental interference attempting to delay or defeat the natural order of things.

In our own day the stage-coach has been supplanted by the steam railroad and stage coaches have practically become a thing of the past. The tallow dip was succeeded by lamps filled with burning fluid or oil, and lamps by illuminating gas, and gas by electricity. These and many other changes were accomplished with no serious disturbance whatever, and so it would be with commodities used as money in the absence of governmental obstruction. There would be no threatening money question in this country today, endangering the continuity and perpetuity of all business activity, if the United States was not engaged in the banking business.

Among civilized people the days of usefulness of silver as money, except in subsidiary forms, are numbered, and silver is going out of use as surely as has the stage coach, and the tallow dip, and for exactly the same reason: civilization has outgrown the conditions which necessitated its use. No money has ever come into use at the behest of government, or because of statutory enactments, but solely because of recognized ability to perform the functions of money. It matters not to what degree of refinement the methods of effecting exchanges may be reduced, or however complicated they may become, the real character of trade is

[illegible] governments have been [illegible] value to money and [illegible] also ceased to have any [illegible] value. the people have come [illegible] derived from but is the result [illegible] could be wider of the truth. [illegible] It is remarkable that such [illegible] accepted by intelligent men. In [illegible] Section has and does frequently [illegible] And in relation to gold and [illegible] the other in every country [illegible] authority of that country attempted [illegible] law different from the exchange value [illegible] by the consensus of opinion in the [illegible] United States foreign coins have fre- [illegible] at a greater price in our own [illegible] they were worth. In support [illegible] stringent legal-tender laws have [illegible] been attached for violation, [illegible] has always remained inopera- [illegible] values was concerned; still the people [illegible] fetich that the government is possessed of [illegible] power in relation to the value and efficiency of

money. And so it is that there is interminable confusion of ideas in relation to money, and we are therefore confronted with a "Money Question." The very air is filled with the meaningless yawp of scheming politicians shouting for "Honest Money." Honest money in what, and of what? And measured by whose standard? An "honest dollar" worth 100 cents. Worth 100 cents in what? A leading candidate for the presidency proclaims in sounding phrase that we must have "a dollar as sound as the government and as untarnished as its honor."

Aside from the implication that it is a proper function of the government to provide the people with money, what do those words mean? If any significance is to be attached — if they are anything more than the bombastic utterance of a vote-catching office-seeker, what do they mean? The government of the United States is no stronger or no sounder than its credit, and its credit is sustained by the exercise of its taxing power. With the knowledge that circumstances have more than once arisen in the past that so impaired confidence in the promises of the United States to pay money that they became unexchangeable, except at a ruinous discount, and in full view of the conditions of the present, when none are so dull as to fail to see that the credit of our country at this moment is stretched to the utmost limit of tension; aye, more! that its credit for more than a year last past has only been sustained by the exercise of autocratic powers on the part of its chief executive dangerous to the very life of republican institutions, which have not failed to arouse apprehensive fear in the mind of every lover of our country when the freedom for which it stands, involving as it does that individual liberty and all that it implies, is again seriously threatened because a government organized to defend and conserve it has engaged in an unwarranted undertaking. While the political stability of our government is sufficient for all proper functions it would seem to be clear that money to be sound and efficient must rest upon a much more stable basis, to wit, value; that sound money must consist of something of such recognized stability that artificial support of any kind will not only be unrequired, but unthought of. Sound money must mean money that under all conditions, unaided, will be able to establish, by the force of its own virtue, its own supremacy in the markets of the world as the best medium of exchange. Gold is the only

[illegible] possessing the essential qualities necessary to supply [illegible] more requirements because the same qualities [illegible]

[illegible] is significant of the fact that the present unfeasibility of things in relation to money is a direct consequence [illegible] governmental interference and is [illegible] that [illegible] adjusted to some more or less the same kind of unintelligent [illegible] governmentalism. In order that a [illegible] [illegible] financial life [illegible] doubt it is absolutely necessary that the government [illegible] from interference and [illegible] [illegible] of the [illegible] business, together with all that is implied in that connection. It cannot be reasonably contended that a people capable of [illegible] and supporting an organization for their own government [illegible] incapable of selecting and adopting the kind of money [illegible] suitable for their own use in their private business. Is [illegible] anyone who will say that under conditions of freedom it [illegible] possible for poor money to circulate upon even terms [illegible] good money? What kind of money do people hide away [illegible] when there is a panic and confidence is destroyed? [illegible] people instantly look up the best money in order that their [illegible] may be safe, why will not the desire for safety in business [illegible] reasonably impel them to always use the best money [illegible] they are only left free to do so?

[illegible] relation to values, it is a mistake to suppose that there is [illegible] any fixed standard. Values are relative and can by no [illegible] be fixed. Money fluctuates in value as does other commodities and for the same reasons, though when the best [illegible] is used its fluctuations are slight and are entirely lost sight [illegible] because the value of everything is measured in terms of the [illegible] in use. The standard must be definite as to quantity and [illegible], but it cannot have a fixed value. Nor can there be more [illegible] one standard of money any more than there can be more [illegible] one standard of weight or extension. For convenience it [illegible] been deemed proper that the government should designate the [illegible] of weight and of measure. It has, therefore, done so [illegible] those standards are absolute, not because of any force of gov[illegible]ment, but because of the very nature of things, and they are [illegible] to designate fixed quantities without relation to anything [illegible]. Values are always relative, never absolute. A dollar may [illegible] a greater quantity today, and more or less of the same thing

tomorrow, or the day after; so the standard dollar of our money, while it is and should be a definite measure, cannot be a fixed measure. The dollar is definite as to quantity and quality, but relative as to value. The stamp of the government cannot go beyond a certification of quantity and quality, and must be in conformity with the already recognized and accepted standard. The dollar was not created by the government, it was in use long before our government was formed and constituted authority simply recognized what had already been accepted and adopted by the people. Is there any doubt in the minds of intelligent people as to what constitutes the now recognized money standard of the civilized world? Does not everyone know that today the intelligent portion of the world is doing business upon a gold basis? That the business of the world is today substantially upon a gold basis is incontrovertible, therefore, it is utterly futile to think of having a money standard out of harmony with the existing state of things. It is just as idle to talk of having a silver standard and expect it to be used by intelligent people as it would be to talk of having a copper standard, and for the same reason. Much weight is given by many to the effectiveness of an international agreement, looking to the establishment of a fixed ratio of exchange between gold and silver, but the absurdity of the idea must become apparent to all when it is recognized that all exchanges are, and must be, based upon real value, and if the governmental agencies of all of the nations of the earth were to agree upon and fix a ratio of exchange between gold and silver the business of the world would in the future, as it has been in the past, continue to be transacted in accordance with their real value, notwithstanding the existence of a coöperative agreement fixing an artificial basis. An economic error cannot be changed to an economic truth by the aggregation of physical force. Copper went out of use as money long ago because silver and gold were better, and now silver is going out of use because gold is better, and it is not at all improbable that the day is not distant when something better than gold will be found and adopted as money.

The advocates of silver say that there is not gold enough in the world to supply the money wants of business, and something must be done to supply the deficiency. How do they know? Who can tell what the money requirements of the world are today.

[illegible] what they may be tomorrow? Whether the people are using the right kind of money or not they should not be coerced into using what they do not desire. All that should be done is to adopt a [illegible] in harmony with fact, and leave the people free to act [illegible] The selection and adoption of a standard has nothing whatever to do with the amount of money required. Suppose the United States officially adopts what is already the recog[illegible] in all business transactions and the people are left [illegible] with interest as indicated to them by [illegible] business can they not always be depended upon [illegible] with which to do necessary busi[illegible] during the panic of 1893 [illegible] law? And were not every[illegible] promises to pay money redeemed? It is not more [illegible] standard of money; then [illegible] legitimate method for the development of [illegible] that the government in the United States should do [illegible] the already existing gold standard; the [illegible] immediately funded into interest-bearing [illegible] United States immediately and [illegible] banking business; repeal all acts of [illegible] free to use such money as each [illegible] There is no more probability of their using [illegible] than there is of their attempting to supply them[illegible] light by the use of tallow candles. Money is [illegible] performing the work required according to its [illegible] work, anyone using inferior tools would be [illegible] and would thereby pay the penalty for the [illegible].

[illegible] that a promise to pay money would [illegible] among intelligent people in these days of [illegible] would be as unreasonable as to [illegible] that people have learned nothing during the past fifty years and [illegible] such a thing were possible it is certainly no part of the duty of government to protect a free people against their own [illegible] intelligent discrimination. Wildcat banking never existed because of freedom, but became possible only through and by the use of the law making power of the state. Did anyone ever hear of dishonest banking being conducted without a charter from the state? There is not a man in the

world with knowledge enough to form an intelligent conception of the banking business who does not know that it is not possible for people doing business with a bank to have any security except such as is afforded by the intelligence and integrity of the *banker*. And that the only effect of legislative attempts to strengthen the security of banks is to impair their usefulness, thereby weakening instead of making them stronger. The state can afford what protection there may be in the punishment of criminal infraction, but beyond that it is wholly powerless. With freedom there would be bad banking, of course, but evils of that kind would soon be corrected and would be of small concern compared to the benefits to be derived under such conditions. Men of honesty and with reputations acquired by honest methods of banking would soon come to the front; no dishonest banker could long compete with a banker who was honest. Under present conditions there is no opportunity for moral considerations to have any force; it is only necessary to make people believe that bankers comply with the law, thereby giving the dishonest banker an advantage over those who conduct their banks honestly and in strict accordance with sound banking principles.

The financial depressions from which we have suffered and by which we are now suffering, have not been due to a lack of money with which to do business, but entirely to a lack or loss of confidence in the stability of the public credit. We have too much money and the best of it is being continuously driven out of the country by that which is poorer by the operation of acts of legal tender. There usually are three kinds of men in public life; there are now but two kinds in this country. Unfortunately for us the statesman has either become extinct upon American soil or else he has gone into retirement. The politician and spoilsman are everywhere present, and these are the men who will have to do with our financial policy so long as the people allow it to remain a public function. The politician is ever a coward; a mere place-hunting demagogue, without convictions in relation to any subject; he is only filled with desire for office and is therefore moved by no consideration except what he thinks will further or advance his personal political purposes. The spoilsman is all that the politician is, and in addition thereto is wholly dishonest. But if these men, who, owing to our own criminal indifference and neglect of political duty, are our law-

givers, were ever so wise and well disposed, they could not cure our financial ills. A system of sound finance cannot be created, it must come about in the only possible way and that is the natural way. It must be a thing of growth, and proper and perfect growth is only possible in the absence of governmental interference. So long as the general government has anything whatever to do with finance beyond the collection and disbursement of its own revenue, we will be disturbed by business panics of greater and greater severity.

Every banker, every man of affairs, our manufacturers and merchants, even down to the smallest, will be in a continual state of fear and uncertainty because of apprehension in relation to what Congress may do. The farmers and wage-workers may not all know what the trouble is, but they will all know that times are hard and they will therefore be in a state of ever-increasing dissatisfaction and unrest. There is but one proper way to settle any question and that is the right way. The money question can only be settled rightly by the United States going out of the business, leaving the problem free for the people themselves to work out a right solution by the use of the knowledge acquired by experience, which they will very speedily and effectually proceed to do.

POWER FOR MOTOCYCLES.

BY LELAND L. SUMMERS.

The comparatively recent impetus which has been given the motocycle is hardly due to any new conditions or circumstances tending to create a demand for the road vehicle, but rather to the evolution of a motor that promises a greater degree of practicability than any that has preceded. The French and the Germans have taken the lead in the development of the modern road vehicle, and have produced a type differing very radically from that of the early experimenters. Two motors are now available that were unknown to the earlier workers, and the more recent progress has been in the application of these to a vehicle. The gas engine, or internal combustion motor, in its various forms and the electric motor are really to be credited with the success of these vehicles.

The designer of a motocycle has at his disposal practically three forms of motive power — steam, gas and electricity — with possibly a fourth in compressed air. Notwithstanding the development which has been made in the application of steam to stationary work, or even to locomotive practice, with the exception of liquid fuel there is little available in this line to the engineer of today that was not available forty years ago. More economical results are obtained in large units; and these units have been increased to an extent undreamed of by the earlier engineer. But in the small units the better proportioning of parts, a more economical expansion and a possible improvement in minor details are practically the only features differing from the earlier practice. The two most important questions pertaining to the motor to be adopted, i. e., weight and efficiency, in the case of the steam engine are both affected by the steam pressure used; this seems to have been recognized by the early investigators as clearly as by the modern engineer with his more thorough knowledge of thermodynamics. It would appear that some of the early attempts were made with steam pressures of 175 pounds, and even 250 pounds per square inch; pressures which would hardly be considered allowable today for ordinary handling,

[illegible] the sectional boilers and improvements both in workmanship and materials of construction. The use of high pressure steam enabled a comparatively light motor to be used; but the auxiliary devices — the boiler, fuel and water — necessitated a cumbersome design, while the difficulties and inconveniences of maintaining a fire under the boiler were serious obstacles.

It is not surprising that attention should be directed toward the internal combustion motor, when its advantages are considered. It is complete in itself — that is, the one piece of mechanism contains the equivalent of furnace, boiler and engine. It may be started almost instantly, without the necessity of kindling a fire or of waiting for steam to be generated; while in addition to all this there is the important factor of economy of operation.

Let us consider the thermodynamic possibilities of the internal combustion motor as compared to the steam engine, and it will be possible then to better understand the advantage possessed by the former. The conditions of maximum theoretical or thermodynamic efficiency will be expressed by Carnot's well-known formula $\frac{T - t}{T}$, T being the absolute temperature of the supply, and t representing the absolute temperature of rejection. The range of temperature worked through is therefore the measure of the thermodynamic efficiency, and any increase of this range will increase the possibility of obtaining a higher efficiency. In the steam engine we have to deal with a medium which is not a true gas, as the pressure increases more rapidly than the temperature, and for this reason the maximum temperature is restricted, as the pressure very soon approaches the limits of the materials of construction. Taking steam at, say, 200 pounds per square inch, gauge pressure, the temperature is only 387° Fahr. or 847° absolute, and if this is expanded to the practical limits of the atmosphere the final temperature would be, say, 213° or 673° absolute temperature, and the maximum or thermodynamic efficiency would be $\frac{847 - 673}{847} = 20.6$ per cent. If condensing apparatus were used, the final temperature could be correspondingly lowered, say a vacuum of 27 inches be maintained; this would correspond to a temperature of about 110°, and the thermodynamic efficiency would become $\frac{847 - 570}{847} = 32.7$ per cent. Thus, it is

evident that the lower limit has been reached, and the only way in which the range of temperature can be extended appears to be by heating the steam independently of the water from which it has been generated. Under these circumstances it can be superheated to almost any degree the lubricants and materials of construction will permit. Modern development seems to tend toward this method of increasing the range of temperature.

M. Serpollet, of Paris, has used superheated steam on his vehicle, and some tests made showed the nominal steam pressure was 58 pounds per square inch, corresponding to a temperature of 306° Fahr., while the temperature of the steam issuing from the boiler was 1,009° Fahr., and the temperature at the steam chest was 572°, the steam being superheated about 266°.

Comparing the steam engine to the internal combustion motor we find that the internal combustion motor starts with the initial temperature of the furnace, while the temperature of the cylinder walls may become the final temperature. Taking a test by Prof. Capper on an Otto gas engine, the temperatures being calculated, we have an initial absolute temperature of 3,503°, and an absolute temperature of mixture after entering cylinder of 605°; the maximum theoretical efficiency was therefore $\frac{3503^\circ - 605^\circ}{3503^\circ} = 82.7$ per cent. It will thus be seen that the gas engine has a maximum theoretical efficiency of four times that of the steam engine under ordinary conditions, and about two and one-half times under the best possible conditions. On the other hand, in examining the *actual* efficiency, or the ratio of the heat turned into work, to the heat actually available to the engine (which is limited by the range of temperature worked through), one finds that the steam engine is far more efficient than the gas engine. In a recent test of a large triple-expansion engine the actual efficiency was 65.9 per cent (that is 65.9 per cent of the energy, obtainable from a perfect engine working through the same cycle, was obtained). The thermodynamic efficiency due to the range of temperature worked through was 31.5 per cent. The thermal efficiency or the ratio of heat turned into work to total heat received was therefore $31.5 \times .65 = 20.7$ per cent. The thermal efficiency of the gas engine mentioned above was 22.8 per cent, so that the actual efficiency was $\frac{22}{82.7} = 27.5$ per cent. The mechanical efficiency of

the steam engine was 89.4 per cent, and of the gas engine 85 per cent, the horse-power developed by the steam engine being 529 and by the gas engine 13. The heat was expended in the gas engine as follows:

Utilized	22	per cent.
Rejected in jacket water	38	"
Rejected in exhaust	40	"
	100	per cent.

If the gas engine in small units can approach the best possible efficiency of the steam engine of large unit working through unusual ranges of temperature, it is evident why the gas engine should be looked upon as involving great possibilities. As only one-fifth to one-quarter of the heat supplied is utilized there appears to be room for improvement. It will be noticed that the chief sources of loss are the high temperature of exhaust and the heat radiated to the jacket water. The early gas engines did not utilize more than five or six per cent of the heat supplied owing to the difficulty of obtaining sufficient expansion and the consequent high temperature of the exhaust.

In applying the gas engine to vehicle propulsion, compressed gas could be used, or the gas may be generated directly from petroleum. Owing to the convenience and compactness of the latter it is used almost exclusively. The more volatile petroleum products, known as gasoline or naphtha, are commonly used, as a suitable gas can readily be made by passing air over or through the liquid. A slight amount of heat aids this very much, so it is common practice to heat the air or petroleum slightly by passing the products of the exhaust around a jacket containing the supply of petroleum. Devices for impregnating the air with the petroleum vapor are usually termed carburetors. It is also possible to simply spray the petroleum through the air as it enters the cylinder and to thus form an explosive mixture.

In considering the electric motor, it is somewhat difficult to compare it with the gas or steam motors, as the cost of operation is dependent upon locality and particular conditions to a far greater extent than either of the other motors; it not being a prime mover, it must depend upon some other source of power. For application to road vehicles there is but one practical way of obtaining this power, and that is from a storage battery. The electric motor itself is superior to any other form of motor from

its portability, ease of control, efficiency and cleanliness, so that the problem really becomes one of a suitable storage battery.

The efficiency of a storage battery depends largely upon the rate of charge and discharge; a small cell may be used and a heavy discharge obtained, so that considerable power may be obtained for a given weight, but this decrease in weight may be accompanied by a corresponding decrease in efficiency. There will also be a very heavy depreciation of the batteries. The recent development in storage batteries has been in the details, and in some respects a returning to earlier types, the cells used for heavy discharges usually being formed under the early method used by Planté in his batteries. The cells used in commercial work are much heavier for a given output than the early type of cells, the present tendency being to diminish the repair and depreciation account. The earlier type of cell offered in the American market would give an output of about six ampere hours per pound of weight, and if we assume an average of two volts throughout the discharge, this would mean an output of twelve watt hours, or equivalent to 31,800 foot pounds per pound of weight. The cells now on the market give from one to four ampere hours per pound of weight, a fair average for ordinary rates of discharge being 2.5 ampere hours, or equivalent to 13,250 foot pounds per pound of weight. A higher rate of discharge can be used and a greater power obtained, but the total energy available will be diminished. Taking as an example one of the cells on the market, we have

Discharging at 5 amperes, capacity	40	ampere	hours
" 7 " "	35	"	"
" 10 " "	30	"	"
Weight of cell, complete	19	pounds	
" elements	14¼	"	

We would then have

1420 pounds per horse-power, with a capacity of	8	horse-power	hours
1010 " " " " " "	5	"	"
710 " " " " " "	3	"	"

and a possible maximum of about 400 pounds per horse-power, with a capacity of 1 horse-power hour. Referring to recent tests we find one vehicle weighing 1,650 pounds; of this weight the battery amounted to 664 pounds, 600 pounds being the elements themselves, and the remaining 64 the containers and electrolyte.

[illegible] fifty cells in the vehicle and they were rated at 50 [illegible] hours at a discharge rate of 5 amperes. It will be [illegible] that there is 15.5 pounds per cell, and that under this normal [illegible] the battery gave 1 horse-power per 980 pounds of [illegible] the actual power available, then, was .67 horse-power [illegible] capacity of 6.7 horse-power hours. Under the first con- [illegible] of the test the discharge was 10.5 amperes, the output was [illegible] horse-power or 490 pounds per horse-power, while under [illegible] condition it was 22.5 amperes, an output of 2.9 horse- [illegible] pounds per horse-power. Under these last condi- [illegible] capacity would hardly exceed 3 horse-power hours. [illegible] is a great gain in output, therefore, there is the corre- [illegible] loss in capacity, but in addition to this there is a heavy [illegible] due to the excessive discharge, as the storage battery [illegible] more physical and chemical ills than any other form of [illegible] the engineer has to deal with.

[illegible] two motors used on this vehicle. The *electrical* effi- [illegible] of each was about 82 per cent under the first conditions of [illegible] about 85 per cent under the second conditions. It [illegible] possible to raise the efficiency somewhat if only one [illegible] were used but it would involve some additional mechanism [illegible] would also prevent the use of the series parallel control. [illegible] storage batteries the voltage of the source of supply can [illegible] be varied and the control obtained in this way, so the [illegible] of the series parallel control of the motors is largely [illegible]. It has, however, the advantage of distributing the [illegible] equally to all cells of the battery, which would not be the [illegible] with the series control of the cells unless a multiple arrange- [illegible] was also adopted for the intermediate speeds or an intermit- [illegible] system employed.

In considering comparative weights per horse-power, it would probably be safe to assume that the gasoline motors weighed about 100 to 150 pounds per horse-power, while the transmission [illegible], supply chambers, etc., represented the balance of weight; the vehicles being of heavy design to withstand the mechanical [illegible] imposed by the weight and moving machinery. If the supply tanks are added, it is probable that the weight would amount to 150 to 200 pounds per horse-power available.

The electrical motors weigh 60 to 90 pounds per horse-power; [illegible] a good design for stationary purposes, using cast steel or forged

fields and pole pieces, weighs about 100 pounds per horse-power in sizes of three to five horse-power, adding 500 pounds per horse-power of storage batteries, roughly estimated, it will require about 575 pounds per horse-power.

The steam motors thus far produced in this country can hardly be considered representative, and it would enable a more just comparison to be made by considering some of the results obtained abroad.

The boilers used by M. Serpollet in some recent light vehicles weighed about 400 pounds, and, in a large vehicle using fifteen horse-power, the weight of the steam apparatus is given as 65 pounds per horse-power. M. Serpollet's boiler is peculiar in that no water reservoir is included in the boiler, the boiler feed being used as a means of regulating the engine. The boiler tubes are very thick and the water is forced through them in a thin sheet so that steam is instantly generated and in the upper tubes superheated. An evaporation of about 8 pounds from and at 212° Fahr. is obtained per pound of coal; a test made with briquettes showed an evaporation of 8.28 pounds from and at 212°, while the engine of 4.5 horse-power showed a consumption of 29.8 pounds of steam per horse-power hour. It will be observed that this is a very much better performance than the best simple non-condensing high-speed engines of large size give, and approximates the performance of a Corliss engine of medium size.

We may expect, then, the weights per horse-power of the various motors to be about as follows:

	Pounds per Horse-Power, Ordinary Conditions.	Best Conditions of Ordinary Practice.
Gas	125— 200	50—100
Steam	150— 300	75—125
Electricity	800—1000	550—750

The utilization of the power furnished will depend largely upon the methods of transmitting the power to the wheels, and the electrically propelled vehicles will possess a distinct advantage in this respect.

If we assume the storage battery to have an efficiency of 60 per cent at the heavier discharge rates which would be used in order to economize weight, and we take the electrical efficiency of the motor as 85 per cent, we have an absolute efficiency of the electrical system of 51 per cent — that is, 51 percent of the power stored in the vehicle will be available for driving the mechanism and the vehicle.

[illegible] as follows:

[illegible]	Available Weight of Motor Per Cent. Energy Available.
[illegible]	1470
[illegible]	3400
[illegible]	747

The last column is obtained by dividing the average weight of the different motors by the figure representing the per cent of energy available. As the figures for the weight of the vehicles are supposed to be based upon equal capacities—that is, equal supplies of fuel and water for the gas and steam engines and the equivalent thereof in the storage battery—the figures roughly represent the comparative advantages as regards weight and efficiency. The difficulties of replenishing will count more severely against the electrical vehicle, but in addition to this the storage battery will be subject to the original losses of charging, which include the losses of the prime mover and also the losses of the generator. In addition to the motor losses we have considered there will also be the mechanical losses in the motors themselves and in the transmitting devices.

The problem of transmitting the power to the driving wheels involves many difficulties, particularly with the gas engine. It is necessary to start the present gas engines without load and then throw the load on; for this reason a countershaft is usually provided and the additional frictional losses may amount to considerable. Gears, belts, sprocket chains and friction drives have all been used for connecting the motors to the shaft or to the drivers; the designs, for this reason, differing very widely, so that no type can be accepted as standard as yet. The arrangement of the driving mechanism and the location of the driving motors are also in a measure experimental. The question of eliminating vibration by the balancing of moving parts and the avoidance of shock from the action of the motor involves some interesting problems of machine design. Many of the vehicles presented at the recent contest of the *Times-Herald* were subject to some criticism from this standpoint.

The simplest designs may not necessarily be the best, all things considered. A single shaft with the wheels mounted solidly, a differential gear being inserted, constitutes a simple arrangement and requires but one sprocket and chain, but the tendency abroad seems to be toward the adoption of two separate sprockets and chains and the insertion of the differential gear in the countershaft. If two separate motors are used there will be no necessity for a differential gear, as the wheels will be driven independently and difficulties from undue friction in making sharp turns, etc., are entirely avoided. Methods of controlling

speed seem to involve the greatest amount of experimental work, for while no difficulty is encountered in accomplishing this result, the methods necessarily entail more or less complication when a motor such as the internal combustion motor in its present form is used. The control of speed by varying the mixture supplied to the motor, while constituting perhaps the simplest form, may be open to some objections from the standpoint of economy.

There are many points which require further experimental data to place them on a scientific basis. It is only due to the liberality of Mr. Kohlsaat, of the Chicago *Times-Herald*, that the present data upon motocycles have been made available. The industry is indebted to his generosity not only for the data but for the interest which has been awakened in this country.

CENTRAL STATION ECONOMICS.*

BY ARTHUR V. ABBOTT, C.E., AND FRANZ J. DOMMERQUE, M.E.

PART II.—CONTINUED.

3. OIL.

When vegetable fiber is subjected to destructive distillation the volatile matter is expelled and the carbon, in the form of charcoal, remains. If the geological theory of the formation of coal from prehistoric forests in the retorts of the rocks be correct, what has become of the enormous amount of volatile matter which the present coal mines but partially represent? The answer is in the oil wells and the gas fields that are usually to be found as companions to the coal beds. This explanation of coal generation is still further confirmed by the existence of an infinite variety in the degree to which the distillation or separation of the volatile portions has proceeded, for in graphitic coal the metamorphosis has extended so far as not only to expel all the gaseous portions, but the carbon has been compacted to such a degree as to become almost incombustible, while in peat and turf the original cellulose is essentially intact.

The knowledge of the existence of petroleum can be traced to remotest history, but this knowledge was coupled with complete ignorance of any value thereunto attached, for it was not until the latter half of the present century that any practical attempt at commercial utilization was made, and only within the past decade that its fuel value, otherwise than as an illuminant, was suspected. Petroleum is chiefly obtained from two localities, one upon the shores of the Caspian Sea and the other the central portion of the United States. Its existence has been discovered in many other places, notably in Peru and Argentine Republic, in Assam, India, China, Japan, Burmah, Egypt, Australia and southeastern Europe, but so long as the central portions of the United States

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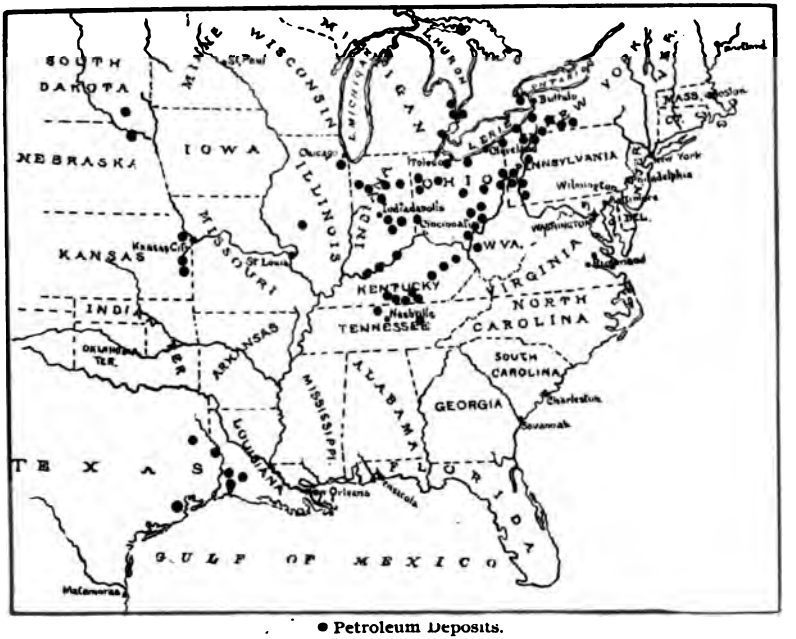
and the oil fields of the Caspian Sea retain their present productiveness it is improbable that other sources of supply will enter into serious competition with them. The output of these wells is so great and the distributing facilities now in existence, in the shape of pipe lines extending to the principal shipping ports on the Atlantic coast of the United States and the Caspian coast of Asia, give such exceptional facilities for economic transportation as to preclude competition from other districts. Russian oil has the advantage over that obtained in America that it is found much nearer the surface and the wells have a much larger flow. The oil area along the shores of the Caspian Sea extends from Baku through the Caucasus to Batoum, a distance of about 560 miles. Here the oil-bearing stratum is found from a depth of 70 to 850 feet below the surface. In this district there are about 400 oil wells, of which the output is about 5,000,000 gallons per day. In America the chief oil supply districts, as indicated in Fig. 1, map of chief oil and gas regions, are in Pennsylvania, Ohio, California, New York and central Canada. The oil, however is found at a much greater distance below the surface, requiring wells varying from 500 to 4,000 feet. In this country there are about 2,500 productive wells, yielding a daily output of about 6,000,000 to 8,000,000 gallons. The following table, No. 29, gives recent statistics regarding the oil production:

TABLE No. 29.—WORLD'S PRODUCTION OF PETROLEUM.

Countries.	Production. Barrels.
United States	50,399,000
Russia, Baku	42,000,000
Russia, elsewhere	251,543
Austria-Hungary	816,000
Canada	798,406
Peru	350,000
India	146,107
Germany	103,323
France	70,000
Japan	48,027
Argentina	21,000
Italy	8,085
Great Britain	1,526
Other countries (estimated)	200,000
Total	84,330,809



● Petroleum Deposits.

FIG. 1. MAP OF CHIEF OIL AND GAS REGIONS.

TABLE No. 30.—OIL PRODUCTION IN THE UNITED STATES.

NAME OF STATE.	NUMBER OF BARRELS.
California	407,179
Colorado	549,390
Indiana	2,335,293
Indian Territory	10
Kentucky	3,000
Missouri	50
New York	1,031,391
Ohio	16,249,769
Pennsylvania	19,283,122
Texas	50
West Virginia	8,445,412

As the output of the oil wells increased, and the demand for petroleum extended over more and more territory, the transportation question became of serious moment. Freight by rail, the oil being inclosed in tanks was the earliest method adopted and is still largely in vogue, being exclusively employed, excepting on the through routes from the wells to the seaboard and to the manufacturing centers. For these trunk lines the expedient of

laying a continuous pipe line provided with relays of pumping stations has been adopted, so that now from the fields of greatest production to Pittsburg and the chief cities on the Atlantic coast steady streams of oil are continuously flowing. The pipe lines are monuments of engineering, being most substantially and carefully constructed and provided with the most efficient of modern pumping machinery. The general location of the principal lines, together with the data respecting them may be obtained from Fig. 2 and Table 31.

TABLE No. 31.—TRUNK PIPE LINES.

	Miles.	Miles.
PITTSBURG LINE, four-inch pipe:		
Bear Creek to Pittsburg		55
BUFFALO LINE, four-inch pipe:		
Olean to Buffalo		56.25
CLEVELAND LINE, five-inch pipe:		
Bear Creek to Simpson	29 81	
Simpson to Warren	30.23	
Warren to Mantua	22.16	
Mantua to Cleveland	28.59	
Total		110.79
PHILADELPHIA LINE, six-inch pipe:		
Colegrove to Hunt's Run	23.41	
Hunt's Run to North Point	25.90	
North Point to Pine	25.73	
Pine to Latshaw	45.40	
Latshaw to Millway	51.94	
Millway to Philadelphia	62.50	
Total		234.88
BALTIMORE LINE, five-inch pipe:		
Millway to Baltimore		65.80
NEW YORK LINE, six-inch pipe:		
Olean to Wellsville	28.54	
Wellsville to Cameron Mills	27.91	
Cameron Mills to West Junction	29.74	
West Junction to Catatonk	27.37	
Catatonk to Osborne Hollow	27.99	
Osborne Hollow to Hancock	29.86	
Hancock to Cochecton	26.22	
Cochecton to Swartwout	28.94	
Swartwout to Newfoundland	29.00	
Newfoundland to Saddle River	28.77	
Saddle River to Bayonne, New Jersey	16.29	
Saddle River to Hunter's Point, New York	12.26	
Total (with loopings)		762.01

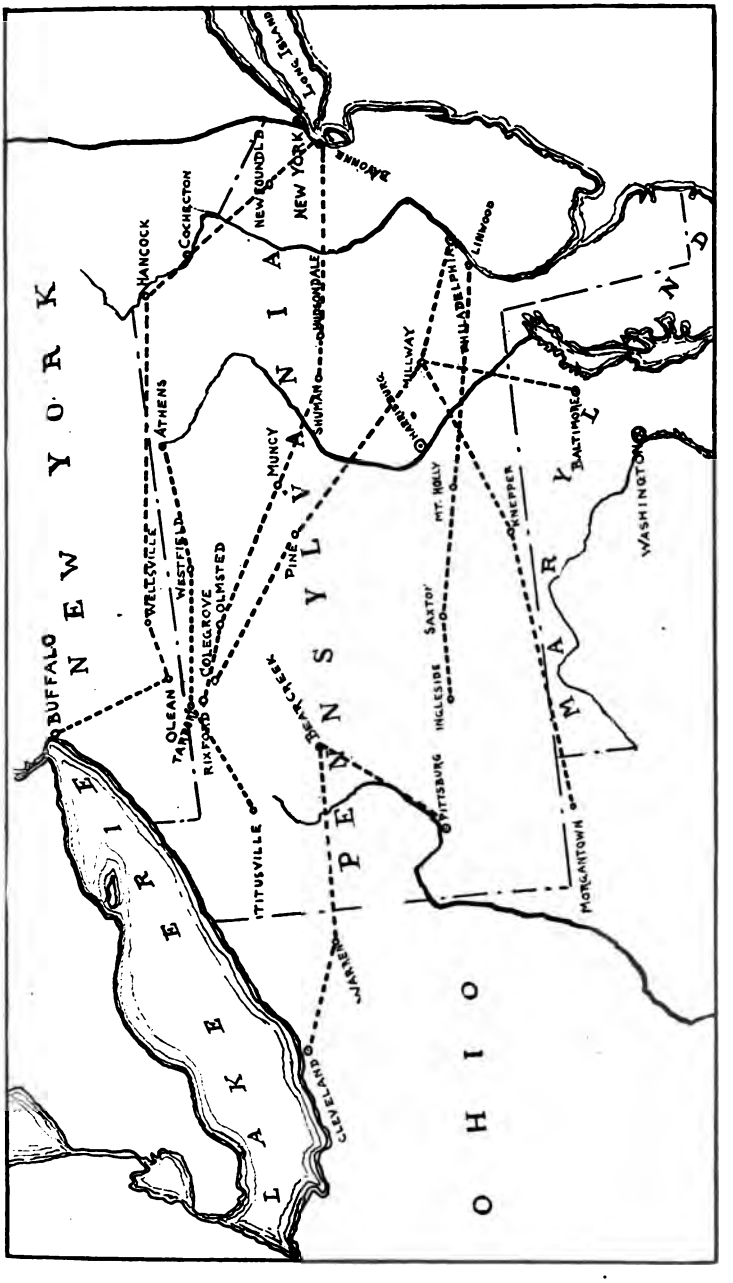


FIG. 2. LOCATION OF MAIN OIL-PIPE LINES.

PIPE LINES

TIDE WATER LINE, six-inch pipe:		
Rixford to Olmstead	28 7	
Olmstead to County Line	36.0	
County Line to Muncy	53.5	
Muncy to Shuman	33.9	
Shuman to Hudsondale	27.65	
Hudsondale to Changewater	52.5	
Changewater to Bayonne, New Jersey	51.5	
Total		283.75
SOUTHERN LINE, eight-inch and six-inch pipe:		
Morgantown to Watson	33.88	
Watson to State Line	35.82	
State Line to Knepper	66.67	
Knepper to Millway	75.42	
Millway to Philadelphia	62.50	
Total (with loopings)		364.29
CRESCENT PIPE LINE (MELLON LINE), five-inch pipe:		
Greggs to Milbank	about 48	
Milbank to Ingleside	" 24	
Ingleside to Saxton	" 30	
Saxton to Mount Holly	" 35	
Mount Holly to Florinal	" 40	
Florinal to Linwood	" 60	
Total		267
UNITED STATES PIPE LINE (EMERY), double line, four-inch and five-inch pipe:		
Titusville to Tarport	about 65	
Tarport to Westfield	" 60	
Westfield to Athens	" 55	
Total (two lines)		360

All these lines as well as the different oil fields, are interconnected again by various pipe systems.

The question of the permanence of oil supply is a vital one, particularly in the relation of the reliability of a fuel supply to a settled branch of manufacture. That the probable supply of petroleum is surely more limited than the coal beds is almost self-evident, and that the possible obtainable quantity decreases with each day's output is evinced by the gradual failure, not only of existing wells, but of entire oil-bearing areas, and the necessity of resorting to the torpedo to stimulate the flagging flow. Per contra, new wells rapidly replace those that are exhausted, and fresh territory is constantly augmenting the probable geographic dis-

tribution of rock oil. In the United States the monopoly controlling the oil trade so skillfully regulates the relation of supply and demand that there is little probability, at least in the near future, of any marked change in price of oil to large consumers.

But statistics also show that the amount of untested area is rapidly becoming less. So the crude oil held in tanks at the end of 1892 amounted to 17,395,389 barrels of 42 gallons each; at the end of 1893 the amount fell to 12,111,183 barrels; at the close of 1894 only 6,336,777 barrels were held, while on March 1, 1895, the stock of crude oil held in tanks fell to 4,908,776 barrels.

Petroleum may also be obtained by the distillation of bituminous shale, or what is technically called petroleum peat. This source was first discovered by Dr. Young in 1850, who endeavored to turn the mineral product to commercial account by extracting therefrom oils which should be of value for lubrication. The quantity of oil obtained from this process is so small in comparison with that furnished by the oil wells as to be of little or no commercial account.

With the first utilization of mineral oil as a commercial fuel, the apparent advantages were such as to give rise occasionally to the impression that oil was likely to entirely displace coal. Nothing, however, could be more erroneous, for the world's total output of petroleum is not over three per cent of the coal consumption, so while in many cases oil fuel may find exceedingly valuable application, from present appearance it is never likely to come into very serious competition with coal fuel, excepting in specific instances.

Petroleum is an oily liquid varying so greatly in density, color and viscosity, that a description broad enough to include all varieties would be almost completely indefinite. The density *may* vary from .750 to over 1.0; the color, from almost pure water-white to a pitch black; and on the one hand, samples are often so volatile as to receive the name of petroleum ether, and on the other, "rock oil" passes by insensible gradations into hardest asphalt. The density is usually about .820, color a greasy reddish opalescent brown with a peculiar and characteristic odor, and unctious feel. All samples have a high index of refraction and are more or less fluorescent. Crude petroleum will give off vapors at a temperature well within the range of summer heat of the temperate zone. As such vapors are explosive when mixed with

[illegible] proportion [illegible] the [illegible] manner: (1) prevent the formation of asphaltic fractions [illegible] (2) prevent [illegible] explosions. [illegible] have [illegible] decomposition [illegible] number of [illegible] links [illegible] round. By this means the low temperature [illegible] the [illegible] means of prevents the formation of [illegible] this [illegible] notable amount [illegible] the [illegible] combination [illegible] as bubbles [illegible] temperature [illegible] the importance [illegible] this precaution becomes. From a chemical standpoint [illegible] consist [illegible] mixture [illegible] varying proportions of large [illegible] complex molecules belonging to the methane series, [illegible] corresponding to type [illegible]. [illegible] results [illegible] the relative proportions [illegible] different hydrocarbon [illegible] in [illegible] the comparative amounts [illegible] curve.

[illegible] CHEMICAL COMPOSITION OF PETROLEUM.

NAME.	FORMULA.	%	%	Boiling Point	Specific Gravity
PARAFFINS.					
Methane	CH_4	[illegible]	[illegible]	[illegible]	[illegible]
Ethane	C_2H_6	[illegible]	[illegible]	[illegible]	[illegible]
Propane	C_3H_8	[illegible]	[illegible]	[illegible]	[illegible]
Butane	C_4H_{10}	[illegible]	[illegible]	[illegible]	[illegible]
OLEFINS					
Ethylene	C_2H_4	[illegible]	[illegible]	[illegible]	[illegible]
Propene	C_3H_6	[illegible]	[illegible]	[illegible]	[illegible]
Butylene	C_4H_8	[illegible]	[illegible]	[illegible]	[illegible]
Pentene	C_5H_{10}	[illegible]	25.70	135	[illegible]
Hexene	C_6H_{12}	[illegible]	25.62	158	[illegible]
Heptene	C_7H_{14}	[illegible]	25.40	208	[illegible]
Octylene	C_8H_{16}	[illegible]	25.30	182	[illegible]
Nonylene	C_9H_{18}	[illegible]	25.30	140	[illegible]
Decylene	$C_{10}H_{20}$	[illegible]	25.22	210	[illegible]
Undecylene	$C_{11}H_{22}$	[illegible]	25.25	235	.....
Dodecylene	$C_{12}H_{24}$	[illegible]	25.30	255	.....
Tetradecylene	$C_{14}H_{28}$	[illegible]	25.00	280	.....
.....	$C_{16}H_{32}$	[illegible]	[illegible]	.....	.....
.....	$C_{18}H_{36}$	[illegible]	[illegible]	.....	.....
.....	$C_{20}H_{40}$	[illegible]	[illegible]	.....	.....
NAPHTHENES					
Naphthene (methyl)	C_6H_{12}	[illegible]	[illegible]	.....	.....
Naphthene (ethyl)	C_7H_{14}	[illegible]	[illegible]	[illegible]	.....

From the preceding data it will appear that on the average petroleum may be credited with calorific power of 20,000 British thermal units, thus having a theoretical calorific power of at least 50 per cent greater than the very best theoretical coal values, and practically double that which is usually obtained from the average of coal fuel. From its ultimate analysis it will be perceived that oxygen is the only deleterious component from a fuel aspect which enters into it. It is also seen that the ultimate composition of petroleums from all sources is quite similar, and from Table No. 8 the necessary data may be obtained for calculating the calorific power of the oil.

Of the American oils, Pennsylvanian petroleum consists chiefly of hydrocarbons of the paraffin series. The lowest members of the series, methane and ethane, though gaseous, are found either in close association or dissolved in it. Thence there have been isolated from it all the normal hydrocarbons of the series up to $C_{13}H_{28}$, as well as several isomers and some higher members.

The aromatic hydrocarbons benzene and its homologues are present in very small amount, if at all in the original petroleum. Very small quantities of naphthenes and olefines are found in Pennsylvanian petroleum. Russian or Caucasian petroleum consists chiefly of homologues of hydrocarbons known as napthenes. Galician and German petroleums are made up mostly of paraffin hydrocarbons with smaller quantities of hexahydrobenzenes, and other aromatic hydrocarbons. Olefines are scarcely found in these oils. In Table 32 will be found the proximate composition of the average output of American wells.

TABLE No. 34.—CONSTITUENTS AND SHALE OIL AND SPECIFIC GRAVITY OF CRUDE PETROLEUM.

NAME OF PRODUCT.	Per Cent.	Specific Gravity.	American Oil.	Shale Oil.
Benzine	1	.725	10	....
Gasoline	3	.775	1.5	....
Kerosene	27	.822	50	35
Naphtha	12	.858	5	5
Light lubricating oil	10	.890	15	2
Heavy lubricating oil	17	.905	....	18
Cylinder oil	5	.915	....	....
Vaseline	1	.925	2	12
Residuum	14	....	6	18
Loss	10	....	10	10

TABLE No. 12—SHOWING [illegible]

	Kind of Oil	Specific Gravity	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Rangoon Burma petroleum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Light "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" Pennsylvania "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Heavy "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" Ohio "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	West Virginia "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" " "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Petroleum from Burma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" " Burma crude	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" " [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" " [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" " Burma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" " Burma crude	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" " Heavy	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Shale oil " Autoville	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Coal tar " Fife gas works	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Petroleum " Balakhany	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Light petroleum from Baku	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Heavy " " " "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Petroleum residue from the Baku factories	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	" " from Java	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Heavy oil " Ogaio	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE No. 32 (CONTINUED).—SHOWING CALORIFIC POWER OF PETROLEUM.

KIND OF OIL.	Spec. Grav.	C %	H %	O %	N %	B. T. U.
Heavy crude....from Russia	.938	86.6	12.3	1.1	....	20,160
" " " "	.938	86.6	12.3	1.1	....	19,940
Light " " "	.884	86.3	13.6	0.1	....	20,630
" " " "	.884	86.9	13.6	0.1	....	21,000
" " " "	.882	87.4	12.5	0.1	....	20,500
Ordinary crude " "	.897	86.5	12.0	1.5	....	19,950
" " " "	.928	87.1	11.7	1.2	....	19,800
Residue .....from Russia	.928	84.9	13.9	1.2	....	18,600
Heavy..... " Pennsylvania	.886	84.9	13.7	1.4	....	19,200
Common ..... " Virginia	.928	88.3	13.9	0.8	....	18,200
Residue..... " "	.860	87.1	11.7	1.2	....	19,200
Shale..... " Scotland	.860	86 5	7.0	0.5	....	19,200
Blast furnace	.886	83.5	10.6	5.9	....	16,750
Heavy crude....from Pennsylvania	.938	84.9	13.7	1.4	....	20,736
" " " Russia	.884	86.6	12.3	1 1	....	20,138
Light " " "	.928	86.3	13.6	0.1	....	22,027
Residuum	....	87 1	11.7	1.2	....	19,832
Petroleum from Oil Creek, Pa.	.730	82.0	14.8	3.2	....	20,890
" " Ohio	.887	84.2	13.1	2.7	....	20,210
" " West Virginia	.840	84.3	14.1	1.6	....	20,910
" " Scotia Well, W. Va.	....	86.62	12.929	....	....	21,240
" " Cumberland, W. Va.	....	85.2	13.359	....	0.54	20,670
" " Hayward Petr. Co., California	....	86.934	11.817	....	1.1095	21,110
" " Bothwell, Canada	.857	84.3	13.4	2.3	....	20,410
" " Petrolea, "	.870	84.5	13.5	2.0	....	20,530

Knowing the composition of oil, the calculation of its calorific power by the principles already given becomes an easy matter. By fractional distillation crude oil may be separated into a great variety of products of different specific gravities. Those which are usually obtained being indicated in Tables Nos. 34 and 35.

TABLE No. 35.—AVERAGE PERCENTAGE OF COMMERCIAL PRODUCTS OBTAINED FROM PENNSYLVANIA, OHIO, NEW YORK AND WEST VIRGINIA CRUDE PETROLEUM. (Sp. Gr. = .800.)

Gasoline	1.5	per cent.
C—naphtha	10.0	"
B—naphtha	2.5	"
A—naphtha	2.5	"
Illuminating oil	54.0	"
Lubricating oil	17.5	"
Paraffin	2.0	"
Coke and loss	10.0	"
	100.0	

As oil fuel does not leave any solid residue on combustion, it is consequently accurate to speak of petroleum as an ashless fuel, at least so far as any provision for the removal of the products of combustion from the furnace, excepting through the office of the stack. Thus, while in the burning of ordinary coal it is customary to count upon from eight to twelve per cent of incombustible residue, for the removal of which provision must be made, this is entirely unnecessary in the use of oil. The ease with which oil fuel may be handled also presents an exceedingly valuable and desirable characteristic. The present practical methods for using oil as a fuel consist in introducing it into the furnace in the form of a spray, which is usually accomplished by atomizing the oil either with an air blast or steam jet. This part of the subject, however, is more properly to be treated under the heading of apparatus, and so will be only incidentally referred to at the present time. Granting that these methods are practical for oil combustion, it is evident that the necessary fuel supply may be conducted at once from storage tanks to the boiler by means of piping, and that the only manual labor necessary in firing a large plant is simply that of regulating the necessary oil supply and the provision for atomizing the spray in the furnace in the proper manner. Thus it is apparent that all labor of handling great quantities of fuel, removing the ashes, etc., is entirely

obviated, and a single attendant is all that is essential even for an exceptionally large plant. As the oil is introduced in the furnace almost in the form of a gas, it may be much more thoroughly and evenly mingled with precisely the necessary quantity of air to produce combustion. In the case of coal it has been shown that from two to three times the theoretical quantity of air must always be supplied to the furnace in order that combustion may be complete. Evidently a large proportion of the calorific power of the fuel is wasted in heating superfluous air and is carried out of the stack at the temperature of the escaping products of combustion. In the case of oil, as the supply of air may be practically regulated very closely to theoretical amount needed, it is easy to greatly improve the furnace efficiency and recover from the products of combustion a much greater portion of their calorific power. It will be also perceived that stacks and other air passages may be made much smaller and much more efficient than it is practicable to accomplish with any solid fuel. It is noteworthy also that, owing to the freedom from ash, all of the slagging effect of the mineral constituents of coal or wood is entirely removed, and the walls of the furnace and grate bars are protected from everything excepting the actual destructive action of the temperature at which the combustion takes place. Furthermore, with oil fuel it is entirely unnecessary to provide any grate bars or other devices for holding the fuel in proper position while burning. As the oil is injected into the furnace in the form of spray, combustion takes place completely during the time that the spray occupies in falling through the combustion chamber, and if this be made of sufficient size and the requisite amount of heating surfaces be provided to absorb the heat from the operation of combustion, no other provision is necessary for a complete combustion plant. There is also at present the practicability of using oil in an internal combustion engine directly, thus avoiding all of the investment and maintenance expense attendant on a boiler plant. For small plants this plan has already proved itself feasible and highly economical, though from existing experience its economy in large stations is as yet doubtful. In England comparisons have been made between the comparative efficiency of oil and coal as fuel; Dr. Sadler, of Middlesborough, stated that 1 pound of creosote oil will evaporate 12.35 pounds of water, while under similar conditions

1 pound of the best Durham steam coal will evaporate 8 pounds of water; he also stated that his experience proves that one ton of oil is economically equal to two tons of coal, allowing for the saving in cost of stoking and other incidental expenses. There are reports of a boiler test in London (a Cornish boiler) where 46 pounds of water were evaporated per pound of oil consumed, and of a test made on steamship boilers of about 100 horse-power giving an evaporation of 41 pounds of water per pound of oil. These cases, though, are exceptional. Thus, it appears that to the credit of oil should be placed a higher calorific power, less labor expense in handling, and a minimum of destructive action upon the combustion apparatus, yet it should be remembered that on the other side the relative expense of oil and coal per unit of weight is decidedly against oil in all but the most exceptional locations.

(*To be continued.*)

ELEMENTS OF COMPLEX QUANTITIES AND VECTORS

WITH REFERENCE TO THEIR USE IN ALTERNATING CURRENT WORK.*

BY FRANZ J. DOMMERQUE, M. E.

MacLaurin's Theorem.—Let y or $f(x) = A_0 + A_1 x + A_2 x^2 + A_3 x^3 + A_4 x^4 + \ldots + A_n x^n$ be given, where the coefficients $A_0, A_1, A_2 \ldots\ldots$ denote quantities independent of x. In order to express the properties or meaning of these undetermined coefficients, deduce successively the first, second, third . . . . n^{th} differentials of the given function:

$$y' \text{ or } f'(x) = A_1 + 2A_2 x + 3A_3 x^2 + 4A_4 x^3 + 5A_5 x^4 + \ldots\ldots + nA_n x^{n-1}$$

$$y'' \text{ or } f''(x) = 2A_2 + 2 \times 3A_3 x + 3 \times 4A_4 x^2 + 4 \times 5A^5 x^3 + \ldots\ldots + n(n-1)A_n x^{n-2}$$

$$y''' \text{ or } f'''(x) = 2 \times 3A_3 + 2 \times 3 \times 4A_4 x + 3 \times 4 \times 5A^5 x^2 + \ldots\ldots + n(n-1)(n-2)A_n x^{n-3}$$

$$y'''' \text{ or } f''''(x) = 2 \times 3 \times 4A_4 + 2 \times 3 \times 4 \times 5A_5 x + 3 \times 4 \times 5 \times 6A_6 x^2 + \ldots\ldots\ldots\ldots + n(n-1)(n-2)(n-3)A_n x^{n-4} \ldots\ldots$$

Put in these equations $x = 0$, and denote the corresponding values of $f(x)$, $f'(x)$, $f''(x)$, $f'''(x)$ . . . . by $f(x)_0$, $f'(x)_0$, $f''(x)_0$, $f'''(x)_0$ . . . . . then we have

$$f(x)_0 = A_0$$

$$f'(x)_0 = A_1$$

$$f''(x)_0 = 2A_2 \text{ or } A_2 = \tfrac{1}{2} f''(x)_0$$

$$f'''(x)_0 = 2 \times 3A_3 \text{ or } A_3 = \frac{1}{2 \times 3} f'''(x)_0$$

$$f''''(x)_0 = 2 \times 3 \times 4A_4 \text{ or } A_4 = \frac{1}{2 \times 3 \times 4} f''''(x)_0$$

. . . . . .

$$f_n(x)_0 = 2 \times 3 \times 4 \times \ldots\ldots nA_n \text{ or}$$

$$A_n = \frac{1}{2 \times 3 \times 4 \times \ldots\ldots n} f_n(x)_0$$

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Substituting the so-obtained values of $A_0, A_1, A_2 \ldots\ldots A_n$ in the given original equation, we have

$$f(x) = f(x)_0 + f'(x)_0\, x + f''(x)_0 \frac{x^2}{2} + f'''(x)_0 \frac{x^3}{2 \times 3} +$$

$$f''''(x)_0 \frac{x^4}{2 \times 3 \times 4} + \ldots\ldots\ldots\ldots$$

$$+ f_n(x)_0 \frac{x^n}{2 \times 3 \times 4 \ldots\ldots \times n} \qquad (98)$$

or, if we choose, we may write MacLaurin's theorem in the form

$$y = y_0 + y_0'\, x + y_0'' \frac{x^2}{2} + y_0''' \frac{x^3}{2 \times 3} + y_0'''' \frac{x^4}{2 \times 3 \times 4} +$$

$$\ldots\ldots\ldots + (y_n)_0 \frac{x^n}{2 \times 3 \times 4 \times \ldots \times n} \qquad (99)$$

MacLaurin's theorem leads to a number of valuable results, but before entering upon these it seems advisable to insert another introductory explanation which is of primary importance, namely, the definition and explanation of series.

D. SERIES OF FUNCTIONS.

An assemblage of quantities which follow each other and which originate from each other by a definite law is termed a *series*. A series can be *finite* or *infinite*. Hitherto we have studied only those series which had an end value, hence were finite; but we could make them infinite also by considering the exponent n as an infinite quantity. An *infinite series* may be either *convergent* or *divergent*. A series is termed convergent when the sum of all its terms does not exceed a definite limiting value, and which reaches this limit only when all of its terms are summed together. We call a series divergent when the limiting value, reached by the sum of all of its terms, cannot be determined. In calculations involving series great care must be taken in their application. They must be used only when they are convergent, as in this case only can all terms after one certain term be neglected without thereby introducing an appreciable error. Any series may be examined for convergency in the following ways: Determine whether the quotient of two consecutive terms of the series remains less than 1, never increasing but decreasing continuously with increasing number of terms; if such is the case the series is convergent, because any geometrical progression containing a constant quotient of a value less than 1

and whose number of terms is infinite is a convergent series, the sum of all its terms being $= \frac{a}{1-q}$, under the assumption that the summation is carried on to and including the last term. This is quickly proved: let a be the first term and q the quotient of the progression; then the sum of all terms is

$$\Sigma = a + aq + aq^2 + aq^3 + \quad . \quad . \quad . \quad . \quad . \quad + aq^\infty$$

or, $\Sigma = \frac{a(q^\infty - 1)}{q-1}$ (by the laws of geometrical progressions).

We may write this

$$\Sigma = \frac{aq^\infty}{q-1} - \frac{a}{q-1}$$

Now, the quotient q being < 1, the above value of Σ can be written

$$\Sigma = \frac{a}{1-q} - \frac{aq^\infty}{1-q}$$

But $q^\infty = 0$, as q is a genuine fraction, hence

$$\Sigma = \frac{a}{1-q} \qquad \text{Q. E. D.}$$

If an infinite series shows from a certain term on a variable quotient which is less than 1 and decreases in value continuously, then the series must be convergent from this term on, and the sum of all its terms will not exceed a certain limiting value. If the limiting value which the nth root of the nth term approaches with increasing n is less than 1, the series is convergent. An infinite series the terms of which are *alternately* positive and negative is convergent always when its terms decrease continuously from a certain term on into infinity. An infinite series of positive and negative terms is convergent always when the series is convergent for all terms having a positive sign.

Convergent series can be added and subtracted, but multiplied only when the series contain only positive terms. If their terms are alternately positive and negative they can be multiplied by each other only when the series remains convergent for all terms having a positive sign. Infinite convergent series can be differentiated term for term only when the so-obtained series are convergent. There exists quite a number of important series, all of which are derived by the application of MacLaurin's theorem. We will give them space here for two reasons: First, in order to make valuable deductions from them, and second as an exercise

[illegible] the obtained values of [illegible] A_1 [illegible] original equation, we have

[illegible] $\frac{[illegible]}{2 \times 3} +$

[illegible]

[illegible] (98)

[illegible] we may write Maclaurin's theorem in the form

[illegible] $\frac{[illegible]}{2 \times 3 \times 4} +$

[illegible] $\times 3 \times 4 \times \ldots \times n$ (99)

Maclaurin's theorem leads to a number of valuable results, but before entering upon these it seems advisable to insert another introductory explanation which is of primary importance, namely, the definition and explanation of series.

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the series is not convergent, as the terms increase; for any value of $\varkappa$ greater than 2 we see that the consecutive terms attain still greater values. If $\varkappa$ is a fraction the terms will decrease, but unless $\varkappa$ be very small the terms decrease so slowly that we shall have to retain a large number of them; thus it will be advisable to deduce some other more convenient form of the logarithmic series.

Suppose we substitute $-\varkappa$ for $+\varkappa$ in above series, then

$$\log_\varepsilon (1-\varkappa) = -\frac{\varkappa}{1} - \frac{\varkappa^2}{2} - \frac{\varkappa^3}{3} - \frac{\varkappa^4}{4} - \frac{\varkappa^5}{5} \ldots \quad (101)$$

and subtract (101) from (100), then

$$\log_\varepsilon (1+\varkappa) - \log_\varepsilon (1-\varkappa) = \frac{2\varkappa}{1} + \frac{2\varkappa^3}{3} + \frac{2\varkappa^5}{5} + \ldots$$

or

$$\log_\varepsilon \frac{1+\varkappa}{1-\varkappa} = 2\left[\varkappa + \frac{\varkappa^3}{3} + \frac{\varkappa^5}{5} + \ldots\ldots\right] \quad (102)$$

Now we may substitute in this equation for $\frac{1+\varkappa}{1-\varkappa}$ the value $\frac{y+n}{y}$, and determine therefrom the value of $\varkappa$ as follows:

$$\frac{1+\varkappa}{1-\varkappa} = \frac{y+n}{y}$$

$$y + y\varkappa = y + n - \varkappa y - \varkappa n$$

$$\varkappa = \frac{n}{2y+n}$$

with this value of $\varkappa$ equation (102) will assume the form

$$\log_\varepsilon \frac{y+n}{y} = 2\left[\frac{n}{2y+n} + \frac{1}{3}\left(\frac{n}{2y+n}\right)^3 + \frac{1}{5}\left(\frac{n}{2y+n}\right)^5 + \ldots\ldots\ldots\right]$$

or

$$\log_\varepsilon (y+n) = \log_\varepsilon y + 2\left[\frac{n}{2y+n} + \frac{1}{3}\left(\frac{n}{2y+n}\right)^3 + \frac{1}{5}\left(\frac{n}{2y+n}\right)^5 + \ldots\ldots\ldots\right] \quad (103)$$

Thus if the value of $\log_\varepsilon$ of any magnitude, y, is known, the $\log_\varepsilon$ of another magnitude greater than y by n units can be found, which expression must be convergent, as the quotient of any two consecutive terms is always less than $\left(\frac{n}{2y+n}\right)^2$ and hence less than 1.

This last form of the logarithmic series is of importance in so far as it gives us the means of calculating a table of Napierian logarithms. Though such tables are plentiful, it seems of interest to devote a few lines to this subject.

If we put in the series (103) $y = 1$ and $n = 1$, we have

$$\log_\varepsilon 2 = 2\left[\frac{1}{3} + \frac{1}{3}\left(\frac{1}{3}\right)^3 + \frac{1}{5}\left(\frac{1}{3}\right)^5 + \frac{1}{7}\left(\frac{1}{3}\right)^7 + \ldots\right]$$

We can calculate this series to any degree of accuracy; the value found will be $\log_\varepsilon 2 = 0.6931471800$.

If we make $y = 2$ and $n = 1$, the series will be written as follows:

$$\log_\varepsilon 3 = 0.6931471800 + 2\left[\frac{1}{5} + \frac{1}{3}\left(\frac{1}{5}\right)^3 + \frac{1}{5}\left(\frac{1}{5}\right)^5 + \frac{1}{7}\left(\frac{1}{5}\right)^7 \ldots\ldots\ldots\right]$$

which gives $\log_\varepsilon 3 = 1.0986122800$.

In the same manner the $\log_\varepsilon$ of 4, 5, 6 . . . . . can be found by always keeping $n = 1$. Though considering that $\log_\varepsilon 4 = \log_\varepsilon (2 \times 2) = \log_\varepsilon 2 + \log_\varepsilon 2$, $\log_\varepsilon 4$ could be obtained also by multiplying $\log_\varepsilon 2$ by 2. Similarly we could find $\log_\varepsilon 6$ by adding $\log_\varepsilon 3$ and $\log_\varepsilon 2$, for $\log_\varepsilon 6 = \log_\varepsilon 2 \times 3 = \log_\varepsilon 2 + \log_\varepsilon 3$.

In this way the $\log_\varepsilon$'s for all figures up to 10 are obtained. It remains to show how to find the $\log_\varepsilon$ of a high number, say, for instance, of 3849763. Our equation tells us to dissolve the number 3849763 into two numbers; in the present case we choose 3849000 for y and 763 for n, hence our equation will read

$$\log_\varepsilon 3849763 = \log_\varepsilon 3849000 + 2\left[\frac{763}{7698000 + 763} + \frac{1}{3}\left(\frac{763}{7698000 + 763}\right)^3 + \ldots\right]$$

In order to find $\log_\varepsilon 3849000$ we must first have in mind that $\log_\varepsilon 3849000 = \log_\varepsilon 3849 \times 1000 = \log_\varepsilon 3849 + \log_\varepsilon 1000$. But $\log_\varepsilon 1000 = \log_\varepsilon 10 + \log_\varepsilon 10 + \log_\varepsilon 10 = \varepsilon + \varepsilon + \varepsilon = 2.30258509 + 2.30258509 + 2.30258509 = 6.90775527$, and

$$\log_\varepsilon 3849 = \log_\varepsilon 3840 + 2\left[\frac{9}{7698 + 9} + \frac{1}{3}\left(\frac{9}{7698 + 9}\right)^3 + \ldots\right]$$

As $3840 = 384 \times 10 = 4 \times 96 \times 10 = 4 \times 4 \times 24 \times 10 = 4 \times 4 \times 4 \times 6 \times 10 = 2^8 \times 3 \times 5$, we find

$$\log_\varepsilon 3840 = \log_\varepsilon 2^8 + \log_\varepsilon 3 + \log_\varepsilon 5$$

$$= 8 \times 0.69314718 + 1.09861228 + 1.60943791$$
$$= 8.25322764$$

and $\log_\varepsilon 3849 = 8.25322764 + 2[0.00117050 + \frac{1}{3}(0.00117050)^3 + \ldots\ldots] = 8.25556864$

and $\log_\varepsilon 3849763 = 8.25556864 + 6.90775527 + 2\left[\frac{763}{7698000 + 763} + \frac{1}{3} \times \left(\frac{763}{7698000 + 763}\right)^3 + \ldots\ldots\right]$

$$= 8.25556864 + 6.90775527 + 2[0.00009910 + \tfrac{1}{3}(0.00009910)^3 + \ldots\ldots]$$
$$= 15.16352213.$$

Of course, the easiest way to obtain the $\log_\varepsilon$ of any number is to use a table of Napierian logarithms, or, if none such is at hand, a table of common logarithms. In the latter case the value found has to be divided by $\frac{1}{\log_\varepsilon 10}$ or 0.4342944819.

Exponential Series, or the expansion of a^x in a series of ascending powers of x.

Again we substitute a new value for $f(x)$ in MacLaurin's theorem, namely, $f(x) = a^x$, and consequently have

$$f'(x) = \log_\varepsilon a \times a^x$$
$$f''(x) = \log_\varepsilon a \times \log_\varepsilon a \times a^x = (\log_\varepsilon a)^2 \times a^x$$
$$f'''(x) = (\log_\varepsilon a)^2 \times \log_\varepsilon a \times a^x = (\log_\varepsilon a)^3 \times a^x$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$f_n(x) = (\log_\varepsilon a)^n \times a^x$$

Making $x = 0$ in the above values of $f(x), f'(x) \ldots\ldots$ and inserting the new values in equation (98), we have

$$a^x = 1 + (\log_\varepsilon a)\, x + (\log_\varepsilon a)^2 \times \frac{x^2}{1 \times 2} + (\log_\varepsilon a)^3 \times \frac{x^3}{1 \times 2 \times 3} + (\log_\varepsilon a)^4 \times \frac{x^4}{1 \times 2 \times 3 \times 4} + \ldots\ldots + (\log_\varepsilon a^n) \times \frac{x^n}{1 \times 2 \times 3 \times \ldots\ldots (n-1)n} \qquad (104)$$

In order to determine whether this series is convergent or not, form the quotient of two consecutive terms, for instance of the $(n+1)^{th}$ and the nth, and see whether it is greater or less than 1.

$$\frac{(\log_\varepsilon a)^n \times \dfrac{x^n}{1 \times 2 \times 3 \times \ldots\ldots (n-1)n}}{(\log_\varepsilon a)^{n-1} \times \dfrac{x^{n-1}}{1 \times 2 \times 3 \times \ldots\ldots \times (n-1)}}$$

$$= \frac{(\log_\varepsilon a)^{n-n+1} \times \varkappa^{n-n+1} \times 1 \times 2 \times 3 \times \ldots \times (n-1)}{1 \times 2 \times 3 \times \ldots \times (n-1)n}$$

$$= \frac{(\log_\varepsilon a)\,\varkappa}{n}$$

Since $\log_\varepsilon 10 = 2.3025850914$ and thus > 2 but < 3, it follows that if we give $\varkappa$ a definite value, say $\varkappa_1$, $\frac{(\log_\varepsilon a) \times \varkappa}{n}$ must be $< \frac{3\,\varkappa_1}{n}$ and thus become < 1 as soon as $n > 3\,\varkappa_1$; hence from this term on the series will be convergent.

We may substitute in equation (104) ε for a, and obtain

$$\varepsilon^\varkappa = 1 + \varkappa + \frac{\varkappa^2}{1 \times 2} + \frac{\varkappa^3}{1 \times 2 \times 3} + \frac{\varkappa^4}{1 \times 2 \times 3 \times 4} + \ldots\ldots\ldots + \frac{\varkappa^n}{1 \times 2 \times 3 \times \ldots \times n} \qquad (105)$$

for $\log_\varepsilon a$ becomes $\log_\varepsilon \varepsilon$ or 1.

In connection with this exponential function the explanation of the exponential curve may be given. The equation of the curve is written in the general form $y = \varepsilon^\varkappa$. If we give $\varkappa$ any positive or negative value we obtain a curve which intersects the axis of Y at the unit point. For if we put $\varkappa = 0$ we have $y = \varepsilon^0 = 1$; the ordinate corresponding to $\varkappa = 1$ is ε or 2.71828182, as $y = \varepsilon^1 = \varepsilon$. With increasing values of $\varkappa$ the values of y increase rapidly; for $\varkappa = \infty$ y becomes ∞, because $y = \varepsilon^\infty = \infty$. On the negative side of the axis of Y the curve will approach the abscissæ axis but never touch it, as for $\varkappa = -\infty$ y becomes $\varepsilon^{-\infty} = 0$, i. e., the abscissæ axis is an assymptote to the exponential curve. Fig. 23 represents the so-obtained curve.

In the equation of the exponential curve $y = \varepsilon^\varkappa$ we may exchange the coördinates; then the equation will read $\varkappa = \varepsilon^y$ or $y = \log_\varepsilon \varkappa$. If we give $\varkappa$ all values from $-\infty$ through 0 to $+\infty$ and plot these values, we obtain a curve of exactly the same shape as the exponential curve, the only difference between the two being their position in regard to the coördinate axes. Fig. 24 represents the logarithmic curve.

Exponential and logarithmic curves appear again and again in alternating-current problems; e. g., in a circuit containing resistance and self-induction, the dying away of the current (after the removal of the E. M. F.) is represented by an exponen-

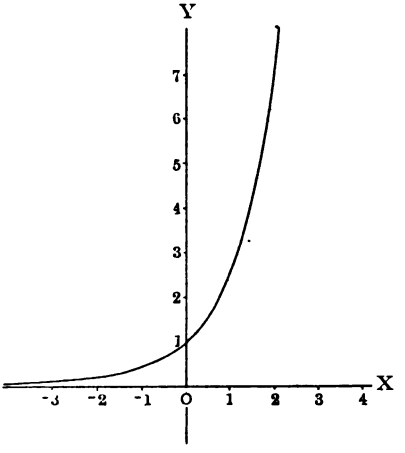

FIG. 23.

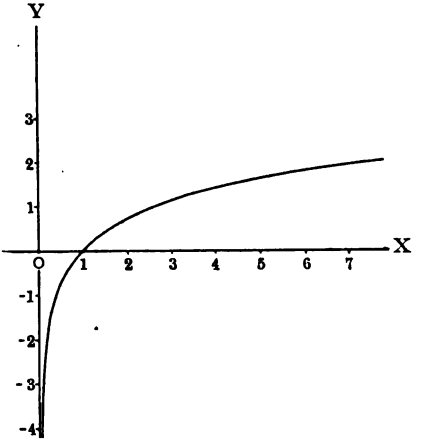

FIG. 24.

tial curve, while the establishment of the current (at any time after the introduction of an E. M. F.) is represented by an exponential curve the ordinates of which are plotted downward from a line parallel to the axis of X at a distance equal to I, the maximum value of the current. Corresponding curves are found in a circuit containing resistance and capacity for the discharge and charge of the condenser respectively.*

* See Bedell and Crehore, Alternating Currents.

(*To be continued.*)

[illegible]

THE BERLINER CONTROVERSY.

BY W. CLYDE JONES.

There is perhaps no question which at the present time is of more importance to the telephone industry than the Berliner controversy now pending before the Supreme Court of the United States on appeal from the Circuit Court of Appeals of the First Circuit.

It is important to the company which owns the patent, as a decision favorable to the patent may insure an exclusive monopoly of the microphone or constant contact transmitter until the year 1908: it is of importance to competing telephone companies, as such a decision would necessitate the employment during that period of the magneto transmitter, while the annulment of the patent would leave the microphone transmitter open to the world.

On June 4, 1877, Emile Berliner filed an application for a patent on an improved form of telephone, and after a pendency of over fourteen years, the patent was issued November 17, 1891, No. 463569. The first and second claims of the patent cover broadly the variable pressure transmitter and read as follows:

1. The method of producing in a circuit electrical undulations similar in form to sound waves by causing the sound waves to vary the pressure between electrodes in constant contact, so as to strengthen and weaken the contact, and thereby increase and diminish the resistance of the circuit, substantially as described.

2. An electric speaking telephone transmitter operated by sound waves, and consisting of a plate sensitive to sound waves, electrodes in constant contact with each other, and forming part of a circuit which includes a battery or other source of electric energy, and adapted to increase and decrease the resistance of the electric circuit by the variations in pressure between them caused by the vibrational movement of said sensitive plate.

On February 13, 1893, a bill was filed by the Attorney-General against the American Bell Telephone Company and Emile Berliner to annul the patent on the ground that the Commissioner of Patents had exceeded his powers in the issuance of the patent, and that the defendants had been guilty of fraud or misconduct in delaying the issuance of the patent. By the sifting process to which the case has been subjected by the

courts, all charges of fraud have been dismissed from the case, and the controversy has settled down to two main subjects of inquiry; first, as to whether the patent is void for illegal delay in its issuance, whether caused by an unauthorized act of the Commissioner of Patents, or misconduct on the part of the assignee of the patent in not prosecuting the application with due diligence; and, second, whether the patent is void because a prior patent was granted upon the same application to the same applicant for the same invention.

The Berliner application was placed in interference with the applications of Bell, Gray, Edison and Voelker, the Bell and Gray applications claiming broadly the method of transmitting speech by the production of undulatory currents, while Edison claimed the carbon microphone and Voelker the microphone broadly. Berliner's claims related to the variable pressure microphone. At that time there was a rule of procedure of the Patent Office providing that when two or more applications *show* the same invention, they should be placed in interference, though they may not claim the same subject matter. The Berliner microphone embodied the broad idea of speech transmission by undulatory currents, and was therefore adjudged to conflict with the Bell and Gray applications, which broadly claimed this invention. The Voelker application claimed the microphone transmitter and was therefore placed in interference, and the Edison application, though limited to the carbon transmitter, showed the microphone broadly, and was therefore placed in interference. The determination of these interferences occupied considerable time and it was not until March 3, 1885, that a final decision was reached awarding the broad claims upon the microphone to Berliner as against Voelker, who was claiming the same structure. It had been previously adjudged that Bell was entitled to the broad claims on the art of telephony as against Gray, who alone of those in interference was contesting this broad claim. Bell and Gray were thus eliminated from the controversy over the microphone. Edison was adjudged to be the inventor of the carbon microphone, thus leaving Berliner and Voelker the only contestants for the microphone transmitter broadly considered, and by this decision of March 3, 1885, priority was awarded to Berliner, so that had there been no other obstacles to the issuance of the Berliner patent, it would have issued at this time.

On July 26, 1880, however, Daniel Drawbaugh filed an application in which he claimed not only the broad art of telephony as claimed by Bell and Gray, but also the magneto-telephone of Bell, the microphone of Berliner and the carbon microphone of Edison. Drawbaugh claimed to have made his invention as early as 1867, and offered to submit proofs of the fact. The application was filed too late to be involved in interference with Bell, Gray, Berliner, Edison and Voelker, but, in addition, there was an objection to the Drawbaugh application which prevented its immediate consideration.

The statute which provides for the grant of letters patent states that a patent shall not be granted upon an invention which has been in public use for two years prior to the date of the application. The courts had held that the prior two years' use, either with or without the consent of the applicant, was sufficient to prevent the grant of the patent. Edison's carbon microphone was introduced into public use in the spring of 1878, and before July was in use to a considerable extent, so that at the date of filing of the Drawbaugh application the microphone had been in public use for more than two years, and such use was thus a bar to the grant of a patent to Drawbaugh. The examiner rejected the Drawbaugh application on the ground of two years' public use, and this decision Drawbaugh contested.

According to the rules of procedure of the Patent Office, an application must be in such condition as to be considered allowable before it will be placed in interference with a conflicting application, so that the Drawbaugh application could not be placed in interference with any other application until the objection to two years' public use had been overcome.

At about the time that the Drawbaugh application was filed, it was assigned to the People's Telephone Company, of New York, and on October 20, 1880, the American Bell Telephone Company brought suit against this company for the infringement of the Bell patents. The People's Telephone Company set up as a defense to this suit the prior invention of the telephone by Drawbaugh, and as the vigor and earnestness with which both parties prepared and presented their cases in this suit promised to definitely settle the question as to whether Bell or Drawbaugh was the inventor of the art of telephony, and as to whether Berliner or Drawbaugh was the inventor of the microphone, the

Commissioner of Patents decided that the quickest and surest way of determining the rights of Berliner and Drawbaugh in reference to the microphone was to await the decision of the court.

On December 5, 1884, Judge Wallace rendered a decision in this suit in favor of Bell as the prior inventor. On December 4, 1885, upon further argument and additional proofs Judge Wallace rendered a second decision in favor of Bell. An appeal was taken from this decision to the Supreme Court of the United States, and on March 19, 1888, a decision was rendered in favor of Bell. The question as to whether Berliner or Drawbaugh was the inventor of the microphone was at the same time determined, as Drawbaugh's claims rested upon the truth or falsity of his story, which was held by the Supreme Court to be a fabrication.

In May, 1888, the Berliner application was rejected on Berliner's intermediate patents and on the ground that his original application was insufficient. This objection was overcome February 25, 1889, and the Berliner application was ready for issuance, but for the fact that the Drawbaugh application was still pending, though rejected because of two years' prior use, which rejection Drawbaugh was still contesting. Public use proceedings had been instituted by the Patent Office, and on October 28, 1891, the Commissioner of Patents affirmed the final rejection of the Drawbaugh application on two years' public use. On the following day, October 29, 1891, the Berliner patent issued.

It is claimed on behalf of the government that the suspension of the Berliner application, pending the decision in the Supreme Court in the suit against the People's Telephone Company, was an unauthorized act of the Commissioner, and that the Bell Company was guilty of misconduct in submitting to such suspension, the effect of which unauthorized act of the Commissioner and misconduct on the part of the owner of the patent is to render the Berliner patent void *ab initio*. Likewise it is claimed that the delay after the decision of the Supreme Court, excepting the period during which the Berliner application was rejected, was an unauthorized act of the Commissioner and misconduct on the part of the owner of the patent. The application was suspended during this period because the Drawbaugh application had not been technically rejected finally and in accordance with the Patent Office procedure on the ground of two years' public use, and it is alleged that since it was evident that the public use preceding

would result in the final rejection of the Drawbaugh application, there was no necessity of withholding the Berliner patent, and that this act of withholding the patent by the Commissioner and the acquiescence in such delay by the Bell Company render the patent void.

Judge Carpenter, of the Circuit Court of the First Circuit, before whom the case was initially heard, stated the case as follows:

> The proposition is that the Bell Company intentionally delayed the prosecution of the Berliner application, and the issue of the Berliner patent, for the purpose and with the result of prolonging their control of the art of telephony, which would cease with the expiration of the Bell patent in 1893; and that they did this by submitting to delays on the part of the officers of the Patent Office, which delays they, the Bell Company, had it in their power to prevent, and refrained from preventing, for an unlawful purpose. This conduct is alleged to constitute a fraud practiced upon the public through the Commissioner of Patents and his assistants. And it is claimed that the patent so obtained by such fraud may be and should be annulled by the decree of the court on the authority of United States *vs.* American Bell Telephone Company, 128 U. S. 315, because there is no substantial difference between a fraud practiced upon the Commissioner as an agent, and a fraud practiced upon the public with the Commissioner's connivance or acquiescence.

The Circuit Court of Appeals remarked that this view of the case practically reduced the inquiry to that of whether the American Bell Telephone Company submitted to delays which it was in its power to prevent, and refrained from preventing for an unlawful purpose, the unlawful purpose being the expectancy of a prolonged monopoly by the delays in the Patent Office. The Court then criticised this position, saying that to lay down the proposition that acquiescence in the delay of a public official who is bound to perform a certain act, involves an unlawful purpose because it may result to the advantage of the applicant, omits an important element; that if the applicant is under no obligation touching the delay there is no rule of law by which it can be said that, because he may receive an incidental benefit therefrom, his purpose in relation thereto is unlawful, since a man's motives will not make wrongful an act which in itself is not wrongful. (Heald *vs.* Carey, 11 C. B. 977, 993.)

The Court also discussed the question in view of the principle of legal ethics that every man is bound to enjoy his own in such a manner as not to interfere with a like enjoyment of their own by

others. On this principle it was contended that the acquiescence of the Bell Company in the delays in the Patent Office was liable to work injury to the rights of the public by prolonging the monopoly of the microphone, thus withholding from the public the right to use the microphone; that the Bell Company was, therefore, under obligation to use the highest degree of diligence in prosecuting the application and avoiding delays, and that the Bell Company should, therefore, have taken every possible means known to the law for hastening the issue of the patent, failing in which the patent was for this reason void. The Court held that an applicant is not responsible for the highest degree of diligence in the prosecution of an application, nor is it necessary to invoke every means known to the law to speed the issuance of the patent.

The Circuit Court held that the patent was also void because of the issuance of a prior patent to Berliner for the same invention. The Circuit Court of Appeals dismissed this point of inquiry on the ground that the Commissioner of Patents in issuing the later patent knew of the earlier patent, and therefore adjudged that the later patent would be valid notwithstanding the earlier patent. As the error complained of was thus alleged to be a mistake of judgment as distinguished from an unauthorized act, which latter alone could render a patent or grant void *ab initio*, the inquiry was not properly before the court. If the officer acted beyond his power and outside the scope of his office, the patent or grant would be void from the beginning; but if he acted within his powers and within the scope of his office and made a mistake in judgment or opinion, decreeing the later patent to be properly issued, the patent could not be declared void in a proceeding founded upon the unauthorized acts of the officer although it might be declared invalid upon proceedings instituted to determine the correctness or error of the officer in making his decision. In the case of patents, where one patent is alleged to be invalid because of prior issuance of a patent for the same invention, the question may be tested in an infringement suit.

Should the Supreme Court, therefore, affirm the decision of the Circuit Court of Appeals, the effect will be to say that the Berliner patent is not void because of any unauthorized acts of the Commissioner of Patents or because of any acts of omission or misconduct of the Bell Company, and will leave undecided the

question whether or not the Berliner patent of 1891 is void because of the issue of the Berliner patent of 1880. Should the Bell Company then bring suit against an infringer upon the Berliner patent the prior patent would be set up as a defense and the effect of the earlier patent would be determined. It is therefore possible that the decision of the Supreme Court, which is being awaited with so much anxiety, may not settle the question. Though the Supreme Court should declare that the patent was regularly granted it may leave the question of the invalidity of the patent on the ground of the issuance of the 1880 patent to be determined by a protracted infringement suit which may carry the first decision directly affecting the competing telephone industry into the next century.

On September 3, 1880, Berliner filed an application as a division of his first application, and a patent was granted on this application November 2, 1880, numbered 233969. Subsequent to the invention of the microphone transmitter, Berliner found that if an undulatory current be passed through two electrodes in constant contact the electrodes will become charged as the current rises, and the charges being of like sign the electrodes will repel each other ; as the current decreases the charges decrease and the electrodes move together, due to the resiliency of the diaphragm. A to-and-fro motion is thus imparted to the diaphragm conforming to the current undulations, and the device acts as a telephone receiver. The construction of the receiver is identical with that of the transmitter, undulatory currents being sent through the electrodes in one case to cause the vibration of the diaphragm, while a vibratory motion is imparted to the diaphragm in the latter case to cause a variation in the pressure of the electrodes and the consequent production of an undulatory current. Claims 1, 2 and 3 of the patent claim the apparatus when used as a receiver. Claim 4, however, is the claim about which the battle is fought ; this claim reads as follows :

4. A system of two or more telephone instruments in electrical connection with each other, each consisting of two or more poles of an electrical circuit in contact one with another, either or both poles of each instrument being connected with a vibratory plate, so that any vibration which is made at one contact is reproduced at the other, substantially as set forth.

This claim is not drawn to the receiver alone, as are claims 1, 2 and 3, nor to the transmitter alone, as are the claims of the 1891

patent, but are to the combination or system comprising two similar instruments, one at each end of the line, so that when one party is talking he uses the instrument as a transmitter while the opposite instrument is a receiver, and when the opposite party is talking the instruments are reversed and the first now becomes a receiver and the second a transmitter.

It is pointed out by the Bell Company that Berliner made the invention of the microphone transmitter in January, and did not discover the adaptability of the device as a receiver until April, and argue that he is entitled to one patent for what he did in January and to a second patent for what he did in April, and that the 1880 patent covers the invention of April: that is, the receiver, while the 1891 patent covers the invention of January, that is, the transmitter. But the Government points out that the claims of the 1880 patent are not confined to the receiver, but that claim 4 contemplates the use of the device as a transmitter. To this the Bell Company replies that claim 4 is for a combination of a transmitter and a receiver: that after the invention of the transmitter and after the invention of the receiver, the idea was conceived of employing two instruments each of which could be indiscriminately used either as a transmitter or as a receiver, and that the applicant is entitled to three patents or claims, one to the device as a transmitter, one to the device as a receiver and a third to the combination of the two devices. The Government argues that claim 4 is not drawn to cover the combination of a transmitter and a receiver as two separate instruments, but that it is drawn to cover the combination of two electrode instruments, each of which has two functions or modes of operation; first, as a transmitter, and second, as a receiver; that having thus claimed a structure having two functions, the applicant cannot afterward take a patent on the same structure to be used for one function only; that the 1880 patent claims a structure comprising two electrodes in constant contact capable of use as a transmitter and also as a receiver, while the 1891 patent claims the same structure, but limits its use to that of transmitting speech.

The Supreme Court has held (Miller *vs.* Eagle Manufacturing Company, 151 U. S. 186) that where a patent has been granted upon a certain structure having two functions, a subsequent patent upon the same structure, but claiming but one of the functions, is invalid. The invention related to a spring of peculiar

shape, which acted upon a plow beam when at a certain height, to press the same into the ground, while, when the beam was at a greater elevation, the spring served to support the beam in an elevated position. The earlier patent claimed the spring of the peculiar shape, having the function of lifting the plow beam and also the function of depressing the plow beam, while the later patent claimed a spring of the same peculiar shape and having the lifting function, no mention being made of the depressing function, which in accordance with the later patent could be performed by the same or by a different spring. The later patent was thus the broader in scope, being limited by the one function, while the earlier patent contained a limitation to both functions. It is claimed that the Berliner patents are wholly analogous to the spring patents, the 1880 patent claiming a structure to be used in its function of transmitting speech, and also in its function of receiving current undulations and reproducing speech, while the 1891 patent claims the same mechanical structure, but limits its use to the transmission of speech only.

If the Supreme Court follows the Circuit Court of Appeals and refuses to discuss this proposition as to the relation of the two patents, the question must wait for a decision until the American Bell Telephone Company sues an infringer, should the patent be not declared invalid because of unlawful issue. Should the patent be declared invalid because of unlawful issue, the controversy will be at an end.

"Is there any hope of an honest act by the United States Senate tending to protect the public in times that are severe enough to exist without the oppression of these blackmailing schemes?

"Is Wall street and Boston to dictate still further what the public shall use by and with the consent of the United States Senate?

"Or shall the state of Illinois expect that it will have one representative with the manhood to make an effort in its behalf and in behalf of its manufacturers?"

In reply to these three questions you propound, I have the honor to state that it has always been my earnest aim to serve the best interests of all reputable manufacturers of legitimate apparatus. Also, to keep my constituents and the public in general informed of the true character of manufacturers who apply to me for assistance in the Senate, and base their regard for the welfare of the public on their own valuation of "half-knave and half-fool — a thing fit only for plucking."

I have the honor to remain,

Your obedient servant, ————.

Senator Cullom might also add to such a communication the query: Has not the leading paper in your city editorially stated: "As for the telephone service, which cheerful prophets declare is going to be vastly cheapened by the expiration of patents, it is essentially a monopoly, and will not be affected by the Supreme Court decision. The value of a telephone depends upon the number of other telephones in use. Each new subscriber not only pays the company for what it has to offer, but adds to its stock in trade. If there were competing companies in Chicago today, the convenience of patrons of both companies would be served by a consolidation. Neither free competition among manufacturers of telephone mechanism nor free competition among telephone companies can be relied upon to protect subscribers from overcharges. When a patent creates an artificial monopoly its expiration is reason for satisfaction. When it merely buttresses a natural monopoly its expiration is utterly unimportant to the people."

FRED DE LAND.

RECENT PUBLICATIONS.

AMERICAN ELECTRICAL CASES. Being a collection of all the important cases (excepting patent cases) decided in the State and Federal Courts of the United States, from 1873, on subjects relating to the Telegraph, the Telephone, Electric Light and Power, and Other Practical Uses of Electricity, with annotations. Edited by William W. Morrill, author of "Competency and Privilege of Witnesses," "City Negligence," etc. Vol. I, 1873-1885, 915 pages; Vol. II, 1886-1889, 935 pages; Vol. III, 1889-1892, 914 pages; Vol. IV, 1893-1894, 911 pages. Albany, New York: Matthew Bender, Law Publisher, 511-513, Broadway, 1895. 6½ by 9½; price, $6 a volume.

The preceding volumes of this set have been reviewed.* In the present volume there are 138 cases reported in full, and memoranda of 136 additional cases, all decided between January 1, 1892, and April 1, 1894. These are arranged by grouping those upon similar topics. The most important feature of the volume is the large number of street railway accident cases reported, fourteen cases being reported of injury to passengers, and twenty-two cases of injury to travelers using the streets. The duties of the telegraph companies as regulated by statute or common law are considered in twenty-seven cases in full, and numerous other cases are cited in notes and memoranda. Fourteen cases relate to the negligence of electrical companies in the maintenance or operation of their apparatus, exclusive of street railway cases. Fifteen cases relate to the rights of abutting landowners in respect to the use of highways for electrical purposes. There are nineteen cases relating to the municipal control of street user, and the power to exact compensation from such user; six to the interference of one user with another; three to the crossing of steam roads by electric railways; two to the status of electrical apparatus as property, while one case considers the power of a municipality to engage in electric lighting. The fourteen cases relating to the rights of abutting owners are summarized as follows: In California it is held that a telegraph line imposes an additional burden, and the contrary is held in Vermont. In New York it is held that the maintenance of telephone lines imposes a new servitude. Pennsylvania held that the maintenance of electric light appliances creates a new burden, while in all other cases it is agreed that the erection and maintenance of the overhead trolley system imposes no new burden for which owners of abutting property are entitled to compensation. Attention is frequently called to the fact, however, that the appliances must be so erected as to create the least possible danger and obstruction in the street. Examination of the particular cases would indicate that special conditions may exist which have influenced the dissenting opinions. Of the nineteen cases concerning the right of electric companies to occupy streets and highways, and of the power of municipal corporations to authorize and direct such occupation, nine relate to the electric railway. The question as to whether street railways can use electricity instead of horses is considered under both the

*ELECTRICAL ENGINEERING, December, 1895.

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power granted by an ordinance or franchise and its legality, and also under the rights of abutting owners. It is held in one decision that even though telegraph and telephone poles create a new servitude, they are not used to facilitate the use of the street directly, whereas the street railway poles and wires are directly ancillary to the uses of the streets in that they communicate the power by which the street cars are propelled. It is held that it is not a question of the motor but the kind of occupation, whether practically exclusive or not, which is the criterion. "The true test in the application of the power in the hauling of street railway cars is, does it interfere with the use of the street by the public? If it does not, or if the interference is slight as compared with the benefits which flow to the public in the use of the street and highway in conformity with the original dedication to public uses, then it cannot be held to impose a new servitude upon the street or the abutting property owners." In the accident cases reported are many points of importance relating to expert testimony. In one case two experts were put upon the stand who testified to the impossibility of a trailer car becoming charged, notwithstanding that the plaintiff's wounds were indisputed and indisputable evidence of the agency by which they were caused, the company made no effort to show that these may have resulted from the motive power used, but through no negligence of those in charge. This was cited by the court as an evidence of the uncertainties and vagaries of electric motive power. To the engineering profession it appears more as a lack of discernment upon the attorney's part, and as a lack of either ability or veracity upon the part of the experts. It is intended that about one volume per year will be added to this set, in that way enabling a complete record to be maintained. Volume IV, like the preceding volumes, will be found a most useful addition to both the electrical and the legal library.

L. L. SUMMERS.

COUNTRY ARCHITECTURE IN FRANCE AND ENGLAND. XV. AND XVI. CENTURIES. From negatives by C. D. Arnold, H. D. Higinbotham and E. A. Stewardson. Buffalo, N. Y.: C. D. Arnold, 123 Bidwell Parkway; 1896. 72 plates, 8 by 10; price, $3.

An attractive collection of half-tone reproductions of some seventy-five photographs of quaint and ancient architecture in France and England, including interior views, courtyards and some picturesque surroundings. There are details of doorways, colonnades, etc., interesting to the architect and the engineer. The presswork is excellent, and as the book is strongly and attractively bound, it will prove a welcome addition to many a tourists' collection.

F. DE L.

FIRST ANNUAL REPORT OF THE BOSTON TRANSIT COMMISSION FOR THE YEAR ENDING AUGUST 15, 1895. Boston: Howard A. Carson, chief engineer, 1895. 85 pages, 6 by 9; free.

The Boston Rapid Transit Commission was appointed under legislative authority to deal with the problem of rapid transit to and in the city of Boston. The commission consisted of the mayor, city engineer, three appointees by the governor and three appointed by the mayor. Fifty-one public meetings were held and numerous engineers and experts employed. The cost of the investigations amounted to about $50,000. A report was

made in April, 1892, recommending various changes with reference to steam railroad terminals, etc. The report was referred to the legislature, and in 1893 a committee of fifteen was appointed to consider the subject. Out of these various committees and legislative acts the present transit commission was established. The present report contains a most interesting consideration of the various problems of elevated roads, the subways and various other propositions for rapid transit. Numerous suggestions are made, and the work is illustrated with plans and sketches. About $1,000,000 has been expended by the commission in various work. A detailed report of the chief engineer also contains some very interesting engineering data.

L. L. S.

ELECTRICITY AS A FIRE HAZARD. By W. J. Jenks. A paper read before the World's Fire Insurance Congress. Schenectady, New York: General Electric Company, 1895. 73 pages, 6 by 9; 12 diagrams; free.

This consists of an elementary treatment of the principles governing the distribution of electricity for the purpose of electric lighting. The practical importance of insulation and the effects of leakage, etc., are very clearly explained and illustrated. This is followed by a résumé of the origin of electrical insurance rules and a consideration of wherein consists the fire hazards of electric light and power systems. Under the head of practical questions of today, are considered the advantages and disadvantages of grounding the neutral wire in the three-wire system. The question of insurance risks is treated, also the inspection problem. The work concludes with tables of the number of fires in various cities and with an enumeration of those originating from electrical causes, including a statement of the losses suffered.

L. L. S.

PRESS-WORKING OF METALS.—A treatise upon the principles and practice of shaping metals in dies by the action of presses, together with a description of the construction of such implements in their various forms, and of the materials worked in them. By Oberlin Smith. New York: John Wiley & Sons, 1896. 276 pages, 6 by 9; 433 illustrations; price $3.

The importance which the press-working of metals has assumed in all manufacturing industry makes the subject one of the most pertinent which the manufacturing engineer has to deal with. In no division of manufacture is there more empirical and dogmatic practice than in that pertaining to dies and the various forming processes. The author has undertaken a most important work, and the subject has been very well treated. The work might readily have been extended and been made to include a more thorough treatise of the subject of dies. Chapter IV is devoted to this subject, but about twenty pages suffice for its treatment. A portion of this work was published about two years ago in the *Metal Worker*, of New York, but the work has been rewritten and a considerable amount of new matter added. The author's aim has been to give general principles covering the work, as he adds "at any rate to a hint-giving extent." The work can hardly be considered a text-book, as those subjects most requiring specific information are dismissed largely with glittering generalities, it being the author's intention, probably, to publish a subsequent work dealing with the power required for shearing, forming, etc. The outline of the processes in

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L. L. S.

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The [illegible] of the law of [illegible] resistance [illegible] measurement. The [illegible] rule of [illegible] plates. The [illegible] of resistance [illegible] fewer and [illegible] with [illegible] the [illegible] of spools [illegible] are [illegible]. The [illegible] resistance [illegible] treated. This [illegible] of [illegible] coils. Chapter [illegible] with [illegible] and [illegible] forms of [illegible] coils. This [illegible] treatment of the Wheatstone bridge, the [illegible] wire [illegible] and the Kelvin and [illegible] bridges. The measurement [illegible] resistance is next considered, followed by a comparison of high resistance by the method of direct deflection. Other methods of measuring high resistance are then treated, followed by the measurement of the resistance [illegible] and electro-motive force, including Mance's method, [illegible] and Carpentier's method. Several appendices are added [illegible] the mathematical theory of the Wheatstone bridge, the electro-motive forces [illegible] in the junctions of meter bridges, the comparison [illegible] resistance and the theory of Mance's method for measuring the resistance of [illegible]. The work will be found of great value and interest to all who have to deal with the construction of resistance coils or the measurement of electrical resistances.

L. L. S.

ELECTRIC WIRING FOR THE USE OF ARCHITECTS, UNDERWRITERS AND THE OWNERS OF BUILDINGS. By Russell Cecil. New York: Macmillan & Company. 1906. [illegible] pages. [illegible] illustrations. Price, $2.50.

This work is a reprint of a series of articles appearing in the *American Architect and Building News*. The treatment of the subject is largely confined to an explanation in detail of the national code of rules for electric wiring, each rule being explained by text and by illustration. The articles attracted a great deal of favorable comment when published in serial form, and the treatment is well calculated to appeal very directly to the class it is intended for. An elementary explanation is given the more common terms, followed by a brief and simple treatment of the calculation of sizes of wire, the systems of distribution and methods of wiring. The national code is then taken up in detail and illustrated with numerous cuts.

L. L. S.

Electrical Engineering

AUGUST, 1896.

POWER FOR MACHINE TOOLS.

BY LELAND L. SUMMERS.

The application of electric motors to the driving of individual machine tools and the displacement of the long lines of shafting, driven either by one large engine or at most by an engine to each department, has made the determination of the power required by the various tools a matter of necessity to the designer. The application of a motor to each individual machine makes it necessary to properly proportion the power to the work required. There is no opportunity for the machines running light to average the power with those running loaded and thus allow a heavier allotment to the machines requiring it; it is imperative therefore that the motors be of ample size, or trouble will always be experienced, yet economy dictates that they shall not be any larger than necessity actually demands.

The electrical driving power enables the power expended to be so quickly, easily and accurately determined, that more complete records of the requirements of the various tools ought to be available. The earlier determinations made by indicating the engine, or in the case of individual machines by the use of a transmission dynamometer, are in some respects still the most complete, or at least are more accessible than the more recent electrical determinations. Many investigators have tabulated the results of extensive tests, and among these may be mentioned the researches of Hartig. Professor Flather has compiled a table principally from this source* which is one of the most complete in the range of tools tested, and the results appear to have been quite accurately determined. These values were obtained by

*American Machinist, April 12, 1894.

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HORSE-POWER REQUIRED TO DRIVE MACHINERY.

Designating Numbers	Name of Machine.	Observed Horse-Power. Total Work.	Running Light.
1	Small screw-cutting lathe, 13½ in. swing, back-geared	0.41	0.18 Varies from 0.15 with, to 0.34 without back gears.
2	Small screw-cutting lathe, 12 in. swing, back-geared	0.330	0.12 From 0.12 to 0.15
3	Screw-cutting lathe, 17½ in., back-geared	0.367	0.207 From 0.16 to 0.466
4	Screw-cutting lathe 20 in. (Fitchburg), back-geared	0.47	0.12 From 0.12 to 0.31
5	Screw-cutting lathe, 26 in., back geared	0.462	0.05 From 0.03 to 0.33
6	Large facing and turning lathe, 80 in. face plate, will swing 108 in., treble-geared	0.53	0.157 From 0.12 to 0.66
7	Large facing lathe, will swing 68 in., treble-geared	0.91	0.37 From 0.39 to 0.81
8	Wheel lathe, 60 in. swing		0.23 to 3.40
9	Small shaper stroke 4 in., work can traverse 11 in.	0.16	0.086 From 0.086 to 0.26
10	Small shaper, Richards capacity 9½ in. stroke by 22 in. traverse	0.24	0.07 From 0.07 to 0.12
11	Shaper (15 in. stroke, Gould & Eberhardt)	0.63	0.21 Varies from 0.001 to 0.47
12	Large shaper, Richards capacity 29 in. stroke by 91 in. traverse	1.14	0.26 From 0.15 to 0.73
13	Crank planer capacity 23 in. by 27 in. by 28½ in. stroke	0.24	0.12 From 0.12 to 0.40
14	Planer capacity 36 in. by 36 in. by 11 feet	0.84	0.27
15	Large planer capacity 76 in. by 76 in. by 57 feet	1.47	0.60
16	Small drill press	0.62	0.39
17	Upright slot drilling machine (will drill slot 2½ in. diameter)	0.41	0.15 From 0.15 to 0.43
18	Medium drill press	1.33	0.62
19	Large drill press	1.24	0.62
20	Radial drill, 6 feet swing	0.53	0.44 Varies from 0.1 with, to 0.44 without back gears.
21	Radial drill, 8½ feet swing	0.67	0.30 Varies from 0.12 with, to 0.80 without back gears.
22	Radial drill press	1.08	0.46
23	Slotter (8 in. stroke)	0.28	0.09 Varies from 0.05 to 0.25
24	Slotter (9½ in. stroke)	0.44	0.22 Varies from 0.15 to 0.65
25	Slotter (15 in. stroke)	0.95	0.57 Varies from 0.43 to 0.94
26	Universal milling machine (Brown & Sharpe No. 1), without overhanging arm	0.28	0.01 Varies from 0.003 to 0.13
27	Milling machine (13 in. cutter-head, 12 cutters)	0.66	0.26 Varies from 0.26 to 0.55
28	Small head traversing milling machine (cutter-head 11 in. diameter, 16 cutters)	0.18	0.10
29	Gear cutter (will cut 20 in. diameter)	0.28	0.11
30	Horizontal boring machine for iron, 22½ in. swing	0.93	0.12 Varies from 0.10 to 0.12 with back gears, from 0.10 to 0.25 without back gears.
31	Hydraulic shearing machine	1.52	0.37
32	Large plate shears (knives 28 in. long, 3 in. stroke)	7.12	0.67

HORSE-POWER REQUIRED TO DRIVE MACHINERY.—*Cont.*

Designating Numbers.	Name of Machine.	Observed Horse-Power.	
		Total Work.	Running Light.
33	Large punch press, over-reach 28 in., 3 in. stroke, 1½ in. stock can be punched	4.41	1.00
34	Small punch and shear combined (knives 7½ in. long, 1½ in. stroke)	0.79	0.16
35	Circular saw for hot iron (30½ in. diameter of saw)	4.12	0.61
36	Plate-bending rolls (diameter of rolls 13 in., length 9½ feet)	2.70	.54
37	Wood planer, 13½ in. (rotary knives, 2 horizontal and 2 vertical knives)	4.24	3.35
38	Wood planer, 24 in. (rotary knives)	3.03	1.42
39	Wood planer, 17½ in. (rotary knives)	4.63	1.25
40	Wood planer, 28 in. (rotary knives)	5.00	0.74 for surface cutters. 0.17 with side cutters.
41	Wood planer, 28 in. (Daniel's pattern)	3.20	1.45
42	Wood planer and matcher (capacity 14½ in. by 4¾ in.)	6.91	4.18
43	Circular saw for wood (23 in. diameter of saw)	3.23	0.70
44	Circular saw for wood (35 in. diameter of saw)	5.64	1.16
45	Band saw for wood (34 in. band wheel)	0.96	0.19
46	Wood mortising and boring machine	0.49	0.34
47	Horizontal wood boring and mortising machine. Drill 4 in. diameter, mortise 8½ in. deep by 11½ in. long	3.68	1.67 Varies from 0.65 to 2.0
48	Tenon and mortising machine	2.11	1.42
49	Tenon and mortising machine	2.73	0.61
50	Tenon and mortising machine	2.25	2.17
51	Edge molder and shaper (vertical spindle)	2.00	1.30
52	Wood molding machine (capacity 7½ by 2½ in., horizontal spindle)	2.45	2.00
53	Grindstone for tools (31 in. diameter, 6 in. face, velocity 680 feet per minute)	1.55	0 32
54	Grindstone for stock (42 in. diameter, 12 in. face, velocity 1 680 feet per minute	3.11	0.24
55	Grindstone	1.08	.62
56	Emery wheel (11½ in. diameter by ¼ in. Saw grinder)	0.56	0.40

dynamometric measurements of the individual machines. No allowance is made for transmission losses in belts or shafting, nor is the character of the work specified, which of course will alter the values somewhat.

From some experiments made at Purdue, the determinations for lathe work showed that about .42 horse-power would be required to remove the metal and from .2 to .3 to drive the lathe, hence .75 horse-power would be an ample allowance for a 14-inch lathe. The work was calculated for wrought iron, and 14 pounds of chips were assumed to be removed per hour, corresponding to a depth of cut of about .125 inches, a feed of about .03 inches, and a cutting speed of about 20 feet per minute. In the milling machines, the machine required .13 horse-power to drive it light, and less than .3 horse-power was required to operate the machine; while doing work, 1.95 pounds of cast-iron chips were milled,

[illegible] only partial. While a [illegible] might have been used, a similar [illegible] effect was obtained by [illegible] cumulative series coil, such [illegible] motors. Prior to the change the [illegible] amperes for the cutting stroke, at the [illegible] the current required was 308 amperes, the [illegible] casting weighing 19½ tons. [illegible] current required was 67 amperes, and at the [illegible] amperes, the casting on the planer weigh- [illegible] interesting comparison made was that in [illegible] time the current required on the cutting [illegible] amperes and when not cutting it was 36 amperes, [illegible] by far the greater proportion of [illegible] in handling the work, the actual cutting [illegible] of secondary importance, and the efficiency [illegible] will probably diminish as the size of the work increases. [illegible] showed that a pipe- [illegible] electrical horse power running [illegible] required 4 horse-power, and thread- [illegible] electrical horse power; cutting a [illegible] electrical horse power, and thread- [illegible] electrical horse power; cutting a [illegible] electrical horse-power, and thread- [illegible] electrical horse power; the motor used [illegible] power and presumably these figures include the [illegible] The highest figures were obtained at a high

cutting speed of 29 feet per minute, which burned the dies, 19 to 20 feet per minute being the average speed. The maximum power for threading a 3-inch pipe at proper speed was 3.2 electrical horse-power. A 5⅝-inch pipe required 2.6 electrical horse-power cutting and 3.5 horse-power threading. This work was on "casing" pipe, using a finer thread than the standard. The ordinary thread of a 4-inch pipe required about 5.3 electrical horse-power, while the cutting required 2.9 electrical horse-power.

A boring bar with four diamond pointed tools boring a cylinder 84 inches diameter and making a ⅜-inch cut with ⅛-inch feed required 8 horse-power.

Tests* made on a punching machine punching cold, 1⅝-inch holes through 1-inch plates:

Required when starting punch empty	13.1	horse-power.
Friction of motor and punch	1.5	"
Motor and punch at time of punching	43.2	"

Two fly wheels of 1,000 pounds each were used on this machine, but neither speed nor diameter were given.

SHEARING HOT STEEL 1 INCH SQUARE.

Motor and shears light	.6	horse-power.
" " " moment of cutting	2.9	"
" " " with compounded field coils	1.7	"

SHEARING COLD STEEL PLATES.

Starting	14.6	"
Cutting 3½ and ⅝-inch plate	5.9	"
" 8 by ⅝-inch plate	11.2	"
" 14 by ¾-inch plate	22 2	"

After fitting motor with a slipping clutch:

Starting	11.7	horse-power.
Cutting 8 by 1-inch plate	10.3	"
" 9 by 1¼-inch plate	17.5	"
" 19 by $\frac{13}{16}$-inch plate	20.2	"

SCRAP SHEARS, SHEARING COLD.

Comparison of shunt and compound winding. 15 horse-power motor. Voltage 220.

	AMPERES.	
	Shunt.	Compound.
Motor and shears, starting	70	50
" " " running	9.11	9.11
Cutting 6½ by ½-inch iron	.....	15.20
" 11 by ¾ " "	60	40
" 11 by ¾ " " again	.....	70

American Machinist, May 21, 1896.

[illegible]

	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible] 10-pound [illegible] steel.

[illegible] per minute.

[illegible]

[illegible] one-horse-power.

[illegible] bearing one [illegible]

[illegible] inch angle. [illegible] 2[illegible]

[illegible] FARRED TO SHUNT WOUND MOTOR.

[illegible] [illegible] of [illegible] inches, feed [illegible] inches per minute

[illegible] [illegible] horse-power.

[illegible] inch deep. [illegible]

[illegible] FOR STRUCTURAL STEEL.

[illegible] revolutions per minute.

[illegible]	[illegible] 7.4	horse-power.
[illegible]	[illegible] 29.3	"
[illegible]	[illegible] 75.7	"
[illegible]	[illegible] 90.4	"
[illegible]		
[illegible]	30.5 — 53.9	"
[illegible]	30.5 — 84.3	"
[illegible]	30.5 — 92.5	"

[illegible] using the power for shearing, punching, [illegible] well known, and the design of the [illegible] affect the results, for the application of fly [illegible] the [illegible] stored in the moving masses may [illegible] the power required. In cutting or [illegible] the dies given the die also is an important [illegible] affect the results. In the large tools [illegible] material being worked is the part moved in [illegible] light load, the question of reversal [illegible] the mass [illegible] the machine

itself, but of the material also, imposes a fluctuating load which necessitates the employment of a motor much larger than would otherwise be necessary. All these problems are of great interest in this day of strenuous effort toward the reduction in the cost of production, and it is necessary not only to have the transmission as economical as possible, but also to see that the method of utilizing the energy does not vitiate the gains made in transmission.

divide the product by the constant number 5,870. The quotient is the centrifugal force, the weight being unity.

Let R = revolutions per minute.
Let D = diameter of circle of revolution.
Let W = weight in pounds.
Let F = centrifugal force in pounds.

$$\text{Then } F = \frac{R^2 D\ W}{5{,}870}$$

Centrifugal force varies as the square of the rate of rotation, directly as the diameter of the circle of revolution, and directly as the weight. Centrifugal force does not vary directly with the periphery velocity of a wheel.

Example: Assume one wheel to be ten feet diameter and another twenty feet diameter: the former would for a given periphery velocity revolve twice as fast as the latter, and its centrifugal force compared with the larger wheel would be $2^2 = 4 \div 2 = 2$.

It would therefore be twice as great in the smaller wheel as in the larger for a given weight of rim. If both rims were of even section the centrifugal force would be equal in both wheels because the weight in the wheel with the greater centrifugal force would be only one-half of that with the lesser centrifugal force.

To estimate the weight of a wheel rim, multiply the section in feet by the mean circumference in feet and by the weight of one cubic foot of the material of which it is made.

Cast iron weighs 450 pounds per cubic foot.
Wrought iron weighs 480 pounds per cubic foot.
Steel weighs 490 pounds per cubic foot.
Dry pine weighs 30 pounds per cubic foot.
Oak weighs 50 pounds per cubic foot.

Example: A wheel is 16 feet in diameter at face, and its rim section is 15 inches face × 16 inches depth. The section is $1.25 \times 1.333 = 1.666$ square feet nearly; the mean diameter is 16 feet — 16 inches = 14 feet 8 inches = 14.666 feet and $1.666 \times 14.666 \times 450 \times 3.1416 = 34.537$ pounds. The centrifugal force of this rim at 90 revolutions per minute would be as follows:

$$\frac{90^2 \times 14.666 \times 34.537}{5870} = 698{,}770 \text{ pounds.}$$

The strain at any point to tear the rim in two is $699{,}636 \div 6.28 = 111{,}406$ pounds.

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limit for belts. The following

table gives proper speeds for wheels of various diameters.

Diameter. Ft.	Inches.	Safe Limit. Revs. per Min. for Heavy Section Without Belt.	Safe Limit. Revs. per Min. for Belt Wheels.
5	0	414	305
5	6	370	277
6	0	345	255
6	6	318	235
7	0	295	218
7	6	276	204
8	0	258	190
8	6	243	180
9	0	230	170
9	6	218	161
10	0	207	153
10	6	197	145
11	0	187	138
11	6	180	133
12	0	172	127
12	6	165	122
13	0	159	117
13	6	153	113
14	0	147	108
14	6	142	105
15	0	138	101
15	6	133	98
16	0	130	96
16	6	126	93
17	0	121	89
17	6	118	87
18	0	115	85
18	6	112	82
19	0	109	80
19	6	106	78
20	0	103	76
20	6	101	74
21	0	98	72
21	6	96	71
22	0	94	69
22	6	92	68
23	0	90	66
23	6	87	64
24	0	86	63
24	6	84	62
25	0	82	61
25	6	81	60
26	0	80	59
26	6	78	58
27	0	76	57
27	6	75	56
28	0	74	55

There are practical reasons for modifying the theoretical dimensions and weights of wheels. One of these is cost. Not only do larger wheels cost more, but in addition they must have larger shafts and bearings to sustain them. Without discussing the limitations either way, the writer wishes to call attention to medium-sized wheels and their conduct under ordinary working conditions in electric lighting and railway service and to present rules for their weights.

In electric lighting service the required power of a wheel depends upon the engine. If one crank is used a larger wheel is required than when there are two or three, as in side by side compound or triple engines. The object of the wheel being to produce an even rate of rotation only. While in railway service the weight of wheel must be so much in excess of that required for even rate of rotation that the number of cranks used does not come into the calculation, the weight of wheel depending in the

One kilowatt = 1.34 horse-power, and one horse-power = 33,000 foot pounds per minute. One kilowatt therefore = 44,220 foot pounds per minute of work. In order, therefore, to estimate the constant force required to drive a generator at one kilowatt capacity (leaving all losses out of account) we divide 44,220 by the velocity of the driving force in feet per minute. Assume a wheel rim to have an even mean velocity of 6,000 feet per minute, the force at center of rim (to drive one kilowatt) is 7.37 pounds. Assume the piston to travel 650 feet per minute, the force required upon it to drive one kilowatt is 68 pounds. It will appear that there are certain fixed relations between the piston, fly wheel and generator, in any particular design, which should be carefully decided upon, so that one being given the other two should be quickly determined. The weight and speed of rim should bear a certain relation to the proposed output of generator and to the power of the pistons. The following are good general rules:

Let A = area of low pressure cylinder.
Let K = kilowatts.
Let PS = piston speed in feet per minute.
Let V = velocity of rim of wheel in feet per minute.
Let W = weight of rim in pounds.

For lighting service $A = \frac{1,700\,K}{PS}$ $\quad W = \frac{120,000}{V}$

For railway service $A = \frac{1,350\,K}{PS}$ $\quad W = \frac{250,000}{V}$

Example: Assume that it is desired to drive, direct-connected, a 600-kilowatt generator in lighting service; the engine to be speeded 150 revolutions per minute and to have 26-inch stroke (piston speed 650 feet per minute); the proper area of low-pressure cylinder is

$$\frac{1,700 \times 600}{650} = 1,723$$

Now, assume the mean diameter of wheel to be 12½ feet. Its velocity is 39.27 × 150 = 5,890 feet per minute. The proper weight of rim according to rule is:

$$\frac{120,000 \times 600}{5,890} = 12,223 \text{ pounds.}$$

The mean circumference of the wheel being 39.27 feet and

the weight 12,223 pounds, the section at 450 pounds per cubic foot is:

$\frac{12,223 \times 144}{39.27 \times 450} = 99.6$ square inches, which is 10 by 10 inches nearly. The wheel therefore would be 13 feet 4 inches diameter and 10 by 10 inches rim section. Its entire centrifugal force is:

$\frac{150^2 \times 12.5 \times 12,223}{5,870} = 585,640$ pounds, and the strain at any point in the rim to tear it apart is $585,640 \div 6.28 = 93,250$ pounds. Assuming that the steel links used in binding the rim together are perfectly safe at 6,000 pounds per square inch, 15.54-inch section would be required. Again, the low-pressure piston is assumed to have 1,723 square inches, as we have already estimated, and its speed 650 feet per minute. The horse-power exerted by one pound mean effective pressure is $\frac{1,723 \times 650}{33,000} = 33.90$. 600 kilowatts will require about 870 horse-power including all losses. This would require about 25.7 pounds mean effective pressure. The rule, therefore, for area of cylinder for lighting service requires 25.7 pounds mean effective pressure at full load. The ordinary load generally is a little under this, requiring in the neighborhood of 24 pounds mean effective pressure at average load, which under 120 pounds steam should be obtained, expanding the steam about 16 times. Some engine builders recommend higher mean effective pressure and some even lower. Possibly a constant of 1,675 would be more nearly correct than 1,700. Assuming, however, the area to be as found by rule, namely, 1,723 inches, and the piston speed 650 feet per minute, that of the wheel being 5,890 feet per minute, the purchase ratio of piston to wheel is $650 \div 5,890 = .11$. One pound at wheel would balance approximately 9 pounds on the piston. When the engine is working under full-rated load requiring 25.7 pounds mean effective pressure, the total mean force exerted on piston is 44,280 pounds, which would impart $44,280 \div 9 = 4,920$ pounds at the rim of wheel. The weight of rim being 12,223 pounds, the acceleration produced by full horse-power of engine, assuming there to be no resistance except the inertia of the wheel rim, would be $\frac{32.6 \times 4,920}{12,223} = 13.00$ feet per second nearly. The normal velocity of rim being about 98 feet per

second, the time required to set the wheel in motion at full speed from a state of rest is $98 \div 13.04 = 7.5$ seconds, about. It follows that when the generator is working under rated load, it alone would bring to rest the wheel from full speed in 7½ seconds if steam were suddenly turned entirely off the engine. It will be seen by working out the cylinder area and wheel for a 600 kilowatt generator in railway service according to the foregoing rule for that work, that the full-rated load would require 32.1 pounds mean effective pressure, which is about 30 per cent above most economical rating, the area of low-pressure cylinder being 1,246 inches, the piston speed 650 feet per minute. The weight of wheel, on the other hand, according to rule, is $\frac{250,000 \times 600}{5,890} =$ 25,450 pounds, which is more than double that required for lighting service. The reason for these differences is that in lighting service the load is generally about constant and pretty nearly or quite up to the rated capacity of the machine, not requiring much wheel force but more cylinder, in order to obtain the best economy in the use of steam; while in railway work the load is very fluctuating, the average being considerably below the rated capacity of the machine, requiring heavy wheel to maintain even speed under sudden changes of load, and less cylinder in order to obtain the greatest possible steam economy at the mean of the fluctuations or average load.

The efficiency of a wheel under fluctuating work depends solely upon its weight and velocity. The efficiency of cylinders as regards regulation depends upon the governor, whether in close or wide adjustment, and as to whether it responds quickly to change of speed. A governor may be so constructed that in counting one minute with rated load on and counting again one minute with load off, the difference of speed will be found not to exceed two per cent, and yet that governor may not be as efficient in actual work as one which would admit of three per cent variation as counted under full load and no load, for the reason that the governor under the closer adjustment may not act as quickly under slight changes of speed. So the power of wheel required for any given service depends in part upon the inherent nature of the governor by which the piston forces which back up the wheel are manipulated.

Assume a quick governor, 600 kilowatt generator, 650 feet

piston speed, [illegible] inches area [illegible] low-pressure piston, and weight of wheel rim at [illegible] feet [illegible] inches [illegible] = [illegible] pounds; the engine compound; one-half the work on each cylinder at rated power of 870 indicated horse-power; what would occur if one-half the load were suddenly thrown off, the governor acting on the high pressure cylinder only. The total force on the pistons at rated load is 32.1 × [illegible] = [illegible] pounds, and its effect at the center of wheel rim about 4,400 pounds. The weight of rim being 25,450 pounds, the force exerted upon each pound of the wheel rim is 25,450 ÷ 4,400 pounds = $\frac{\quad}{[illegible]}$ = [illegible] pounds nearly. One pound being equal to 32.17 force units, [illegible] of a pound = 5.46 force units. That is to say, if all the load were suddenly thrown off and the same mean effective pressure maintained on the pistons, the engine would speed up at the rate of 5.58 feet per second. The normal speed of wheel being [illegible] feet per second, the per cent of acceleration per second with whole load suddenly thrown off is about 5½ per cent — an increase in speed of wheel at the rate of 334.8 feet per minute. When one-half the load is suddenly thrown off, the acceleration is 5.58 ÷ 2 = 2.79 feet per second, and the acceleration is at the rate of 2¾ per cent. Now, assume the governor to move through its whole range up to point of cut-off required to carry full load upon 2¾ per cent in variation in speed, it will be seen that before the engine had actually slowed down 2¾ per cent the governor would have shut the steam off the first cylinder entirely, and reducing thereby the mean effective pressure by direct control one-half, just meeting the change in load. While the governor is making this change, however, it is reducing the mean effective pressure, so that the time the engine would work under full mean effective pressure after the load was thrown off would depend upon the quickness of the governor. The actual variation under a theoretical governor could not exceed 1⅜ per cent. If, however, the governor required one second (under 2¾ per cent acceleration) to begin to move (as is frequently the case) the fluctuation in speed would exceed 5 per cent. The quicker a governor responds to change in speed the smaller may be the wheel as compared to any number of kilowatts capacity in the generator and inches area in cylinder.

TELEPHONY.*

BY DR. V. WIETLISBACH, OF BERNE, SWITZERLAND.

(*Continued from page 410, Vol. VII.*)

THE HUMMING OF WIRES.

Very troublesome is the humming of wires, especially where they are carried over a roof, below which are inhabited rooms. In case the humming cannot be overcome, the removal of the wires is very often demanded, such rooms being rendered disagreeable at night. It is well to take means at the start to mitigate, or if possible to prevent the humming.

A wire strung through the air acts like a cord under tension. The insulator supports are the end-points of the cords which may move in two ways, either in simple progressive waves, or in continuous vibrations.

If a wire is struck with a stick, a wave passes several times to and fro across the wire, growing weaker and weaker, and soon dying away. Such vibrations are not troublesome, as they die out quickly and are too slow to give out an audible tone. Of very different importance are the continuous waves, when the whole wire assumes a condition of steady vibration. A violin string, for instance, performs such a motion as long as the bow is drawn across it. Each single particle of the string then vibrates continuously, executing a to and fro motion about its point of equilibrium.

To produce such a continuous motion requires a constant and symmetrically undulating force, i. e., periodically increasing and decreasing. Such a force is afforded by a slight but steady wind, which first carries the wire away from its point of equilibrium until its elasticity overcomes the force of the wind. Then it returns to that point, but with unequal velocity, for the tension is not everywhere equal, being greater at the supports than at the center. Hence a real equilibrium is impossible, and continuous vibrations set in, the cause of which must be looked for in the constantly acting pull of the wind and the unequally acting elas-

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ticity of the wire. These vibrations, of course, obey the same laws as those of strings in general. In such a continuous vibration there exist so-called crests and knots, the latter being the points which remain perfectly quiet during the motion, while the former perform the greatest motion. In general, the motions are the greater the tighter the wire is strung. Also the pitch of the tone increases with the tension.

A great variety of devices exist to prevent humming, based on two different principles.

In the one class of these devices the wire is inclosed in a solid body near the insulators. This acts as a damper on the crests of the vibrations, and thus prevents the parts of the wire near the fixture from humming. But the middle portions of the wire, especially in long spans, may be set vibrating all the same, so that this remedy fulfills its aim only in part. It is usually applied by pressing around the wire a cylinder of wood about 5 cm. (2 inches) long, lined with felt, or by winding the wire with tarred hemp or a spiral of lead wire 5 cm. (2 inches) in diameter, and about 5 cm. (2 inches) long. Such devices, being attached to the wire itself, have the great disadvantage that the places covered by the damper, which retains moisture, become subject to chemical action. Electric currents are of course very favorable to chemical action.

The second method of preventing humming is free from this disadvantage. It consists in making the supports of the wires movable, thus allowing the differences in tension to become equalized and preventing continuous vibration. For instance, if a violin string, instead of being wound tight about its pin, be attached to it by a rubber band, it could no longer be set into strong vibration. To produce a similar result with a telephone wire, it is not wound directly around the insulator, but the latter is provided first with a rubber or felt sleeve, which in turn may be sheathed with tin, then the wire is attached to the sleeve. Better yet is the following device: A piece of rubber hose of about 15 mm. (0.6 inch) outside, and 1 mm. (.04) inside diameter, and 10 cm. (4 inches) in length, is slit lengthwise and the wire laid inside. A piece of sheet lead is then pressed about it, and it is fixed to the insulator in the usual manner.

The rubber loses its elasticity after a few years, and if the tension on the wire is severe, it will soon work through the hose.

FIG. 202.

FIG. 203.

This remedy, therefore, is practicable for small wires only, say to 1½ mm. (.06 inch) and for short spans.

Under difficult circumstances the chain damper (Fig. 202) does very well. This consists of a chain a meter long, carrying at each end a porcelain knob. The chain is fixed to the insulator, the wire is cut and the ends attached to the porcelain knobs the same as to insulators. The two sections of the line are connected by a separate piece of wire. The chain damper is probably the most effective damper, but it is very troublesome to apply and keep in order. Instead of the chain, a spiral steel spring may be used, attached to the insulator and at each end connected to the wire. Here there is no separate connection required, as the steel spring answers the purpose. (Fig. 203.)

The use of dampers interferes with the maintenance of good insulation and a symmetrical sag, and is, therefore, to be avoided wherever possible. The simplest way to prevent humming is to increase the sag, that is, to reduce the tension on the wire, but this, when carried too far, involves other drawbacks, such as tangles; but getting rid of dampers is a great advantage.

MECHANICAL FEATURES OF THE LINE.

The construction of a telephone line is determined mainly by electrical considerations. To answer its purpose the wire must offer the least possible resistance to the electric current, and must be insulated as well as possible so as to prevent both the escape of its own current and the access of foreign currents.

These considerations mainly determine the choice of the wire and the mode of attaching it to the supports.

In order to answer its purpose permanently, the line must be mechanically capable of resisting the influence of weather for any length of time, and the strength of the supports must fulfill mechanical requirements.

We proceed to discuss briefly the forces that come into play, and which are to be regarded in the erection of fixtures and poles.

1. *Strains and Wire Stretching.* — Most important is the stretching of the wire, for on the one hand the strain of the tightened wires on the fixture (their weight as vertical load and their tension as horizontal pull) is by far the greatest, and therefore conditions mainly the strength of the fixture; while on the other hand the wire itself may break if badly stretched. A wire string between two points A and B of equal height forms a so-called catenary, and, the sag being very small in comparison with the length of the span, the arc is approximately a parabola and may be regarded as such.

Let

a = distance between poles,
l = length of wire,
f = sag of wire,
g = weight per unit of length,
S = strain at lowest point of curve,

then on the above assumption (by the laws of geometry and mechanics)

$$S.f = \frac{g.a^2}{8} \tag{1}$$

$$l = a + \frac{8 f^2}{3 a} = a + \frac{g^2 a^3}{24 S^2} \tag{2}$$

From this the shape of the curve (the amount of sag) and the strain S can be calculated for any case.

The strain S' at any point of the wire equals the strain S at the lowest point of the same plus the weight of a length of wire which is equal to the perpendicular elevation of the point under consideration above the lowest point, and is therefore at the points of support:

$$S' = S + g f \tag{3}$$

and becomes a minimum where

$$f = \frac{a}{\sqrt{8}} = 0.35\, a$$

Thus, if it is desired to stretch a wire so that the strain shall be as small as possible, the sag must exceed one-third the distance between poles. If the sag be further increased, the weight of the wire increases faster than the strain decreases.

In practice these formulæ are only approximately correct. There are two other elements affecting the wire — the temperature of the air and its own elasticity.

The wire expands with heat, lengthening and increasing the sag. The expansion is approximately proportional to the increase of heat. Let α = the coefficient of expansion, i. e., the amount of expansion of the unit of length for an increase of heat of 1° Cent., then the length l of the wire when heated t° Cent. becomes $l\,(1 + \alpha\, t)$ and formula (2) will now be

$$(4) \qquad l\,(1 + \alpha\, t) = a + \frac{8 f^{1^2}}{3\, a} = a + \frac{g^2\, a^3}{24\, S^{1^2}}$$

As l and a are nearly equal, the following relation exists between the sags f and f^1 before and after the elevation of temperature:

$$(5) \qquad \alpha\, t = \frac{8}{3\, a^2}\,(f^2 - f^{1^2})$$

and between the strains

$$(6) \qquad \alpha\, t = \frac{g^2\, a^3}{24}\left(\frac{1}{S^{1^2}} - \frac{1}{S^2}\right)$$

With rising temperature the sag increases and the strain decreases very fast, and vice versa the strain increases while the sag decreases with falling temperature. As lines are built mostly during the warm season while good weather prevails, the sag is to be calculated so that with falling temperature the strain shall not exceed a certain limit, the allowable or safe tension point of the wire. The safe point of copper and bronze wire is usually taken at ⅓ of its breaking strain, of iron wire at not over ⅙. It must be considered that iron wire is unequally corroded by rust in course of time, thus materially reducing its breaking strain.

In stringing a wire enough sag must be allowed so that the strain at the lowest temperature to be expected shall not exceed the safety point. This lower temperature varies according to the climate, so that no general rule can be laid down.

The temperature coefficients of expansion are as follows:

For copper . . . . . 0.00[illegible]
" bronze . . . . . 0.00[illegible]
" iron . . . . . 0.00[illegible]

When a wire is stretched its length does not remain constant, but increases by elasticity.

Let E be the co-efficient of elasticity, then the expansion caused by the strain S is $E \cdot S$ per unit of length, and the original length becomes

$$L = l_0 - E \cdot S_0.$$

For a smaller strain S' the length becomes

$$L' = l_0 - E \cdot S'$$

and similarly the contraction due to a decrease of strain from S to S' $L' - L = E \cdot (S - S')$.

When thus the temperature increases by t the wire is elongated by $l_0 - \alpha \cdot t$ on account of expansion through heat, and shortened by $l_0 - E \cdot (S - S')$ on account of the simultaneous lowering of the strain, so that the resultant of both tendencies is:

$$(7) \qquad l_0 - \alpha \cdot t - E \cdot (S - S') = \alpha - \frac{S^2 \alpha}{3a} = \alpha - \frac{S^2 \alpha}{3a}$$

Using these factors we get from equations (2), (5) and (6), with abbreviations, the relation between the sags:

$$(8) \qquad \alpha \cdot t - \frac{E \cdot a^2}{S} \cdot E \left(\frac{s - s'}{s - s'} \right) = \frac{S}{3a} \cdot (s^2 - s'^2)$$

and between the strains

$$(9) \qquad \alpha \cdot t - E \cdot (S - S') = \frac{S^2 \alpha}{24} \left(\frac{s - s'}{S - S'} \right)$$

From these equations of the third degree the values of temperature, sag and tension can be calculated, though the calculation is somewhat laborious.

The coefficient of elasticity is:

For copper 0.000080
For bronze 0.000078
For iron 0.0000043
For steel 0.0000040

In addition to the elastic change in length, which disappears again as soon as the wire is relieved of mechanical strain, sometimes, mostly under a heavy load, a change in length is effected which remains even after the cessation of the strain; thus the

wire becomes deformed. Wires of high permanent elongation (soft wires) are not adapted to line construction, as the sag and strain relations would be continually changing, and it would be impossible to maintain the line in serviceable condition. Hence the wire chosen for line construction must be as elastic as possible, and the strain required to cause a permanent elongation must be as great as possible, and close to that which corresponds to the safety point of the wire.

To facilitate calculations of sag and strain, we give elsewhere tables from which the values for ordinary cases may be taken.

STRENGTH OF SUPPORTS.

The supports that carry the lines must be strong enough to bear the load safely; at the same time they must resist the lateral forces which tend to bend or break the pole or fixture.

We must thus distinguish between vertically directed forces, which weigh down the support, and horizontally directed forces, which pull it sideways; these are to be considered separately.

1. *Downward Stress.*— Let V be the load at the point O of the pole, with a vertical force such as just to cause crushing (load limit),

h the distance of point of application of this load from the ground level,

E the modulus of elasticity of the material of the pole,

I the moment of inertia of cross section of pole; then

$$V = \frac{E\,I\,\pi^2}{4\,h^2}$$

The average modulus of elasticity is:

For wood $E = 110{,}000$ kg. per cm.^{2} (1,564,530 lbs. per sq. inch).
For cast iron $E = 1{,}000{,}000$ (14,223,000 " " ").
For wrought iron $E = 2{,}000{,}000$ (28,446,000 " " ").

The moment of inertia for a circle of diameter d is $I = \frac{\pi\,d^4}{64}$ and for a ring-shaped cross section of outside diameter D and inside diameter d, $I = \frac{\pi}{64}(D^4 - d^4)$; for a rectangular cross section of height a and width C, $I = \frac{ba^3}{12}$; for a square cross section, where a is the length of each side, $I = \frac{a^4}{12}$.

Of the theoretical load P, however, only a certain fraction,

$\frac{1}{n}$, can be utilized consistently with safety, this fraction, of course, being smaller for less reliable material, and vice versa.

The safe load is thus

$$V = \frac{I}{n} \times \frac{E I \pi}{4 h^2}$$

where $\frac{1}{n}$ is

for wooden poles about $\frac{1}{10}$,
for cast-iron poles about $\frac{1}{8}$,
for wrought-iron poles about $\frac{1}{6}$.

The size of the load V is determined primarily by the weight of the pole and the wires carried by it. Mechanically weak structures will carry this normal load, but it is more difficult to provide for chance loads. The most dangerous loads of this kind are snow and sleet on the wires, which may run up to 6 kg. per meter of wire (4 pounds per foot).

Prudence recommends using strong poles, especially in mountain districts and wherever much snow and ice are to be expected.

2. *Side Stress.*—The pressure of wind acts on the pole horizontally, also the pull due to the strain on the line wires when the pole stands on a corner or when the spans on both sides are unequal. These forces tend to pull over the pole and thus keep it under tension.

The force of the wind pressure is determined by the velocity V and the direction of the mass of air in motion against the opposing surface; also by the extent and form of the latter.

Let P be the wind pressure in kg.,
F the opposing surface in sq. meters,
v the velocity of air in meters per sec.,
g the weight of one cu. meter of air in kg:

Then the wind pressure on a directly opposed surface is

$$P = c\, F\, v^2\, g.$$

The empirical coefficient c is not quite constant, but varies somewhat with the extent of the surface.

Approximately $P = 0.122\, F\, v^2$.

If the wind strikes the surface not directly but at an angle α then

$$P = 0.122\, F\, v^2 \sin^2 \alpha.$$

The maximum declination from the horizontal in ordinary winds is about 10°.

If the opposing surface is not plane but cylindrical, as is the case with poles, the wind pressure according to d'Aubuisson is

$$P = 0.085\, F'\, v^2$$

Hence the pressure of wind per square meter at velocity

$v =$ 1 m. (hardly perceptible wind)	is =	0.08 kg.
$v =$ 10 m. (strong wind)	=	8.5 kg.
$v =$ 15 m. (storm)	=	19.10 kg.
$v =$ 20 m. (hurricane)	=	34.0 kg.

Though the wind pressure, as the formula shows, depends also on the extent of the opposing surface, this dependence may be neglected, as the surfaces to be taken into account (poles and wires) are of no great continuous extent.

The second force acting horizontally is the pull of the line wires. If the supports of the wires are in a straight line, and if the wires are strung so as to be under the same strain on both sides of the support, then the wires exert a vertical pressure depending only on their weight and acting in the direction of the length of the pole, tending to bear it down, as shown above.

This favorable case does not often occur, for, besides the vertical pressure, there are always forces acting horizontally on the support, owing to the following causes :

1. If the supports, though standing in a straight line, are unequally distant, the strain on both sides is equally great at a certain temperature only. As the temperature changes, the strain changes also, and may increase on the longer or shorter span according to circumstances (quality of wire, proportion of pull at normal temperature), as shown by the tables of sag given elsewhere. From these tables the resulting horizontal strains may easily be found.

2. If three consecutive supports, a, b, c, do not stand in a straight line, but form an angle w at point b, a horizontal force results, the direction of which lies inside the angle formed by the lines, and the value of which may be calculated from the parallelogram, in Fig. 204 ; if P_1 and P_2 are the strains on the lines on both sides of the support b, then the resulting horizontal strain is

$$R = V\,(P_1^2 + 2\,P_2^2 + P_1\,P_2 \cos w)$$

3. If the lines do not run horizontally, i. e., if the supports

[illegible] on the same level, which is the case if buildings of unequal height are used to carry the supports, then the strain of the line wires tends also to break the support in the vertical plane through the line. Let [illegible] be the angle formed by the line with the horizon, then the resultant R of the line strain, which acts at right angles to the plane of line, forms the same angle [illegible] with the vertical support, and the vertical component which tends to break it is (Fig. 205)

$$= [illegible]$$

and the horizontal component, which tends to bend the support, is

$$= [illegible]$$

The horizontal force acts close to the top of the support and the greatest stress is at its base. Let h be the length of the lever (height of the point where the force acts above the base), then the moment of the horizontally acting force F is Fh. This moment is opposed by the support with the moment $K W$, where W represents the moment of resistance of the cross section and K the safe load of the material per unit of cross section. To maintain equilibrium, Fh must be less than $K W$.

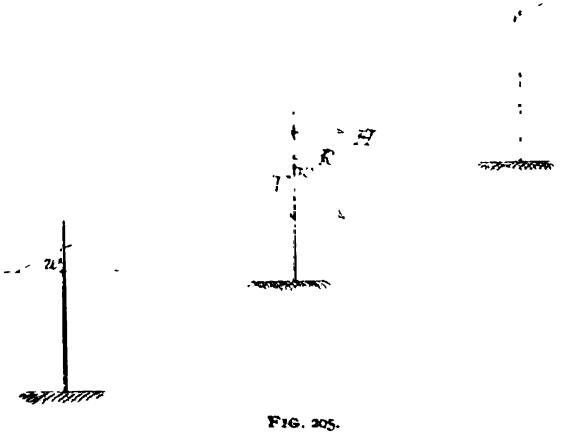

FIG. 205.

Hence the load limit K on the pole by the force H acting horizontally is

$$K_1 = \frac{Hh}{W}$$

The moment of resistance W for the circular cross section of diameter d is

$$W = \frac{\pi d^3}{32}$$

for the ring-shaped cross section of exterior diameter D and interior diameter d is

$$W = \frac{\pi}{32} \frac{D^4 - d^4}{D}$$

for the rectangular cross section of height a and width b,

$$W = \frac{b \times a^2}{6}$$

for the square cross section, having each side $= a$,

$$W = \frac{a^3}{6}$$

The safe load K for different materials is :

For wood, 75 kg. per cm.^{2} (1,067 lbs. per sq. inch).
For cast iron, 250 " (3,556 " " ").
For wrought iron, 700 " (9,956 " " ").

3. *Resultant Strains.*—Now, the vertical load V and the horizontal strain H act simultaneously. The safe vertical load per unit of surface for cross section F is

$$V_2 = \frac{V}{F}$$

and the safe horizontal strain

$$V_1 = \frac{Hh}{W}$$

thus the total load at the base point is

$$V = V_1 + V_2 = \frac{Hh}{W} + \frac{V}{F}$$

The adjoining figure shows the distribution of the strains over the cross section at the base under combined action of the vertical and horizontal forces. (Fig. 206.)

The static calculations by this formula are mostly very complicated. In general V_2 is much less than V_1, and it is sufficient to calculate the lateral strains only.

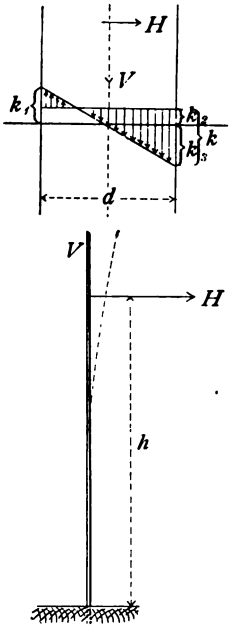

FIG. 206.

Examples.— Our calculation may be applied to an iron cable pole as illustrated in Fig. 192. The pole has a height of 16.3 m. (53′ 6″), and is square. The corners are formed by angle irons, connected and stiffened by lattices. The column is to carry 100 wires, stretching in all four directions. The cables lead up to the insulators through the inside of the column, the insulators being attached to the four sides of the insulator cage. The strain on each wire may be taken at 30 kg. (66 pounds), the total strain in each of the four directions being thus $30 \times 25 = 750$ kg. (1,650 pounds), or including wind pressure,

$H = 800$ kg. (1,760 pounds)

in round numbers.

When the wires are tightened in all four directions, the horizontal pull equalizes, and the column is loaded vertically only by the weight of the wires and the column itself. But some of the wires may break. The most unfavorable case is where only one side carries wires. We want to build the column strong enough so that it does not fail in this case either.

Besides this one-sided pull H from the wires we may have wind pressure also. The column has a surface of 6 m.^{2} (64½ square feet). The wind pressure in a storm, when the velocity is 40 m. (130 feet), amounts to 180 kg. per m^2., hence the wind pressure on entire column = 1,080 kg. (2,376 pounds).

If an approximate result will answer the purpose the calculation can be simplified by assuming the wind pressure distributed equally over the length of column, then by linear cm.,

$$H = \frac{1080}{1630} = 0.67 \text{ kg. } (3\tfrac{3}{4} \text{ pounds per linear inch}).$$

The strain of wires acts at the center of the insulator cage 15 m. (49.2 feet) above ground level, while the wind pressure acts at the center on the part of the column under consideration.

The combined deflecting strain on the column, according to the equation given above, will be

$$K\,W = H\,h + H_1\,h_1$$

Where $H = 800$ kg. signifies the strain of the wires, h the distance of the point of action of the forces above the assumed point of the column,

$$H_1 = \frac{H h_1}{2} \text{ is the wind pressure,}$$

and h_1, the length of column measured from the assumed point. The moment of resistance W must be calculated for the different points of the column, so that the load V remains throughout below the safe limit of 700 kg. per mm². for wrought iron.

For the base of the column

$$700\ W = 800 \times 1500 + \frac{0.67 \times 1630^2}{2}$$

and $W = 2986$ is obtained,

while for a point at the height of 2 m. 70 (8′ 10¼″)

$$700\ W = 800 \times 1230 + \frac{0.67 \times 1360^2}{2}$$

$$W = 2292$$

For a point at a height of 5 m. (16⅓ feet.)

$$W = 1754$$

and a height of 14 m. (46 feet.)

$$W = 123$$

The cross section must be made so large that the moment of resistance attains everywhere at least the above values. The column is built of angle iron with equal flanges.

Fig. 207 is the cross section of a brace column, composed of four different sections, namely :

(1) The angle iron A of 60 by 6 mm. (2.4″ by ¼″) cross section, the whole length of the column.

(2) The angle iron B of 65 by 5 mm. (2.6″ by .2″) cross section, up to a height of 5 m. (16′ 5″) above the ground level.

(3) The angle iron C of 75 by 5 mm. (3″ by .2″) cross section, the whole length of the column.

(4) The angle iron D of 80 by 5 mm. (3.2″ by .2″) cross section, up to 2.5 m. (8′ 2″) above ground.

The angle irons A B and C D are placed one on the top of the other ; between B and C a space is left for braces of strap iron.

At the base the column is 68 cm. (27″) square.

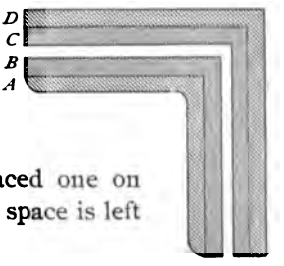

FIG. 207.

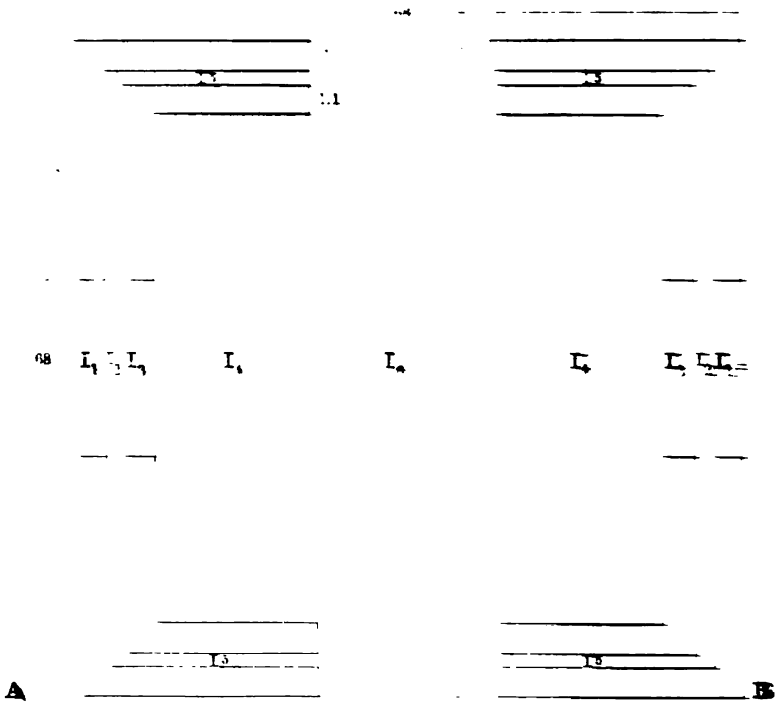

FIG. 208.

At a height of 2.70 m. 8′ 10.4″) it is 59 cm. (23.6″) square.
" 5 m. 16′ 5″) it is 51 cm. 20.4″) "
" 14 m. 46′) it is 23 cm. 9.2″) "
" 16.3 m. (53′ 5″) it is 16 cm. 6.4″) "

The moment of resistance W equals the moment of inertia I divided by distance y of the furthest point from the center.

$$W = \frac{I}{y}$$

y is half the width of the column. The moment of inertia of the cross section is easily calculated in the following manner: Let I be the moment of inertia of the entire square in relation to the line $A\ B$ and I_1, I_2, I_3, I_4, I_5, I_6, the moments of inertia of the rectangles shown open in the drawing, then the rectangle of the cross-hatched area is $I = I_t - (2\ I_1 + 2\ I_2 + 2\ I_3 + 2\ I_4 + 2\ I_5 + 2\ I_6)$. (Fig. 208.)

For the base of the column

$$I = \frac{68^4}{12} - \left(2 \times \frac{1.52^3}{12} + 2 \times \frac{0.5 \times 66^3}{12} + 2 \times \frac{1.1 \times 52^3}{12} + 2 \times \frac{5.4 \times 62.8^3}{12} + 4 \times \frac{6.5 \times 0.5^3}{12} + \frac{52 \times 68^3}{12}\right) = 1217872$$

hence the moment of resistance

$$W = \frac{I}{C} = \frac{1217872}{34} = 3581$$ (Calculated maximum strain 2986)

For the cross section at the height of 2.7 m. similarly

$W = 2357$ (calculated strain 2292)

at the height of 5 m.

$W = 1778$ (calculated strain 1754)

at the height of 14 m.

$W = 722$ (calculated strain 123).

The proposed cross section thus satisfies everywhere the calculated deflection moments, i. e., the iron is everywhere loaded under 700 kg. per cm².

If the column has to bear a heavy strain — for instance, if the wind pressure is severe on one side, or if the wires pull in one direction only — it will bend. To investigate the mechanical processes in play here, let us calculate the extent of deflection. Let us assume that the wires, n in number, are all on one side, those on the other sides having been either cut or broken down.

The strain of the n wires

$$S = \frac{n\,g\,l^2}{8f}$$

This equation holds good for the case where the column stands straight and the wires normally branch out in different directions. If now the wires are broken on all sides but one, the head of the column will lean in that direction by a certain amount x, so that the length of the span is now $l - x$ only. Thus the sag increases, let it be f^1, and the strain decreases; it will be

$$S^1 = \frac{n\,g\,(l-x)^2}{8\,f^1} \qquad (1)$$

The displacement x of the top of the column is by the theory of the strength of materials

$$x = \frac{S^1\,H^3}{3\,E\,I} \qquad (2)$$

Where E is the coefficient of elasticity and I the moment of inertia of the cross section. This equation holds perfectly good only when the cross section is everywhere the same, which is

[illegible]

[illegible] the [illegible] of [illegible] material [illegible] $\frac{1}{2}$ another [illegible] between the sag [illegible] and after the deflection depends [illegible] the wires remaining the same or

$$[illegible] = [illegible] \qquad (3)$$

[illegible] the relation of small [illegible] between the strain S' of the wires and the bending moment of the column is

$$[illegible] = \frac{[illegible]}{[illegible]} = [illegible] \qquad (4)$$

[illegible] we know —

[illegible] span.

[illegible] height of pole.

[illegible] and [illegible] number and the weight of the wires.

[illegible] coefficient of elasticity of the material selected.

[illegible] and [illegible] the sag and strain of the wire in normal state.

The following quantities are unknown

[illegible] the deflection of the pole top.

S' and f' the strain and the sag of the wires after the deflection

I and y the moment of inertia and the distance of the extreme point of the cross section from the center.

K the safe load of the material.

These are governed by the four relations (1) to (4), hence two of them may always be assumed arbitrarily. Usually h is determined by the selection of the material, and an assumption of the value of the deflection or of the allowable sag resulting from the same may be made, and we will do so here. The sag should not exceed a certain limit, so as not to interfere with traffic in the street. If thus K and f' are assumed as known, then from (3) we get

$$l = \frac{1}{2} + \frac{4}{3}\frac{f'}{l} + \sqrt{\frac{l^2}{4} + \frac{4}{3}f^2 + \frac{16}{9}\frac{f^2}{l^2} - \frac{8}{3}f'^2}$$

Calculating from this the equation (1) gives the value of S', (2) the value of I, and (4) that of y, so that not only the moment of inertia but also the size or cross section is determined.

Let us apply the formulæ to a pole built up of angle and channel iron, 10 m. (32 feet 9 inches) high, and carrying 60

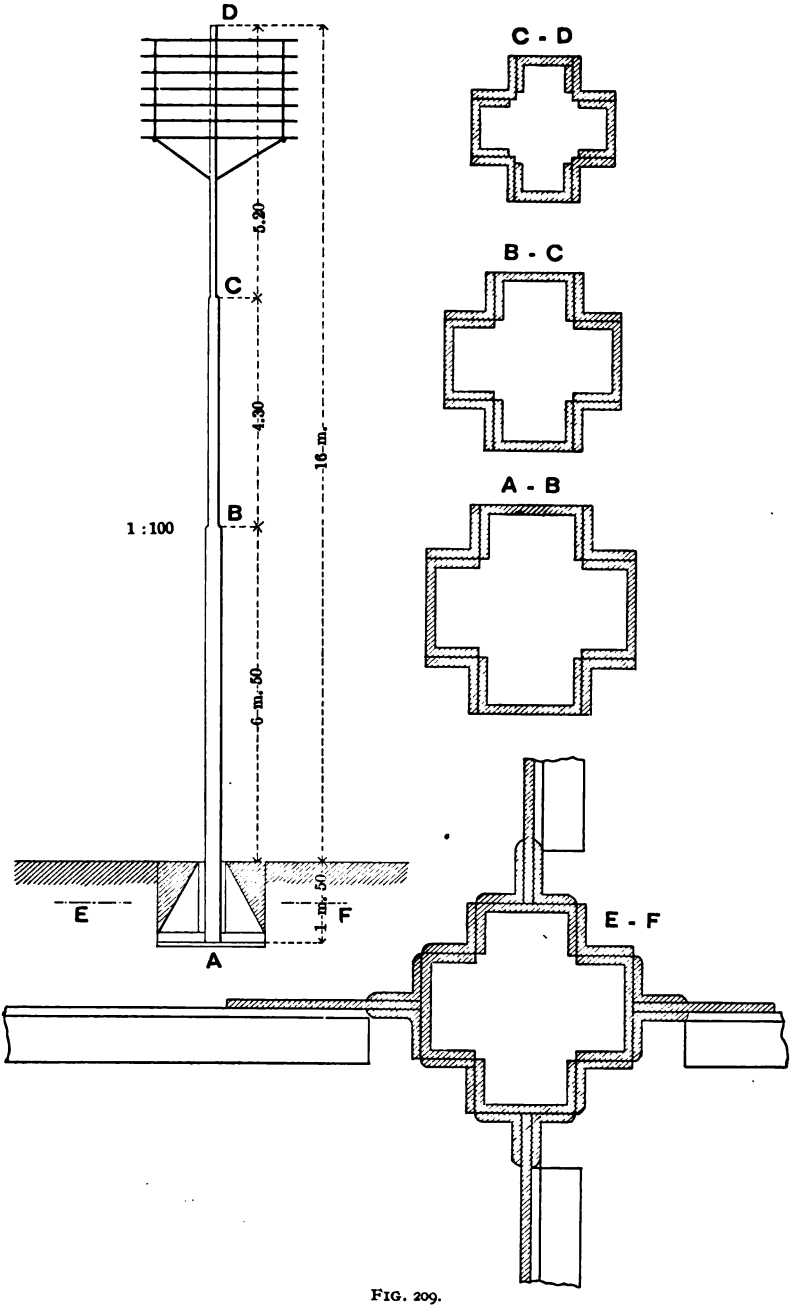

FIG. 209.

bronze wires of 0.8 mm. (.032 inches) diameter. The weight of the wire is 5 gr. per m. The strain on each wire is 5 kg. (11 pounds), and the span on both sides is 100 m. (328 feet) long. Should the wires break, the pole would bend. By the above formulæ the deflection under these assumptions is 25 cm. (10 inches), the strain $S' = 113$ kg. (240.6 pounds), and the sag $f' = 330$ cm. (13 feet 2 inches). The load at the base of the column is 580 kg. per cm.^{2} (8,250 pounds per square inch); at the points B and C 500 kg. per cm.^{2} (7,111 pounds per square inch), hence does not exceed the safe limit of 700 kg. per cm.^{2} (9,956 pounds per square inch.) (Fig. 209.)

Though the column is thus not able to resist the entire pull in its normal position, there is no fear of a break, as the strain decreases very fast with the deflection. But the deflection causes a lasting deformation; also molecular strainings and displacements reducing its strength considerably. Hence it is preferable to construct the columns so as to resist the strain of the wires without deflection.

b. CROSS-TALK.

In telephony a large number of wires must be carried on the same route. Thus arises the remarkable phenomenon of cross-talk on long lines, i. e., the conversation on one wire may also be understood by listening in on a parallel line. This property is attributed to induction, and here a distinction must be made between electrostatic and electro-magnetic induction.

Electrostatic induction is caused by charge and discharge currents. Any two wires together form a condenser of a certain capacity, each wire forming one of the plates. Let k be the electrostatic capacity of both wires to each other per unit of length, then the charge induced in the second wire, having an electromotive force e in the first wire, is

$$q = -e\,l\,k$$

l being the length of both wires.

If the electro-motive force in the first wire changes, then the charge in the second wire changes also and the surplus flows to earth through the telephones in circuit. The amount of this surplus, or the intensity of the charging currents, is thus

$$\frac{dq}{dt} = l\,k\,\frac{de}{dt}$$

half of which flows in each direction, and thus the intensity of

the currents generated by the electrostatic induction amounts to

$$c_1 = \frac{lk}{2} \times \frac{de}{dt}$$

The value of the constant of electrostatic capacity for two wires of radius r distant d from each other and distant h from ground is

$$k = \frac{\frac{1}{2} ln \left(\frac{\sqrt{d^2 - h^2}}{d}\right)}{\left(ln \frac{2h}{r}\right)^2 - \left(ln \frac{\sqrt{d^2 - 4h^2}}{d}\right)^2}$$

The electro-magnetic induction produces also secondary currents of a certain intensity. The electro-motive force e generates a current

$$C = \frac{e}{w}$$

in the line it is acting upon. Here w, the so-called electric inertia, represents the known quantity $\sqrt{R^2 + m^2 L^2}$ where R = resistance, L = self-induction and m = frequency of the undulating electro-motive force. Let h be the mutual electro-magnetic induction constant of the two wires to each other per unit of length, then the current induced in the second wire by the original current C is

$$C_2 = \frac{lp}{w_1 w_2} \times \frac{de}{dt}$$

which flows to earth by way of the telephones connected in the second line.

The value of the electro-magnetic induction constant is

$$p = 2L \left(ln \frac{2l}{d} - I\right)$$

Ordinarily both inductions act together and influence each other so as to render the process pretty complicated.

The electro-magnetic and electrostatic inductions may be distinguished in the following manner:

In the electrostatic induction the charge flows from the center of the line in both directions to earth. Thus there is a neutral point at the center, whence the induction currents start to the right and to the left, and if a telephone is inserted here it remains silent, while telephones connected to the ends of the line respond to the induced current.

In the electro-magnetic induction, on the contrary, the induction currents are of equal strength throughout the line. The telephone at the center of the line thus responds only to the electro-magnetic induction currents, but not to the electrostatic, thus affording means to distinguish the two inductions. (Carty.)

The relations between k and p show that for long aërial lines electro-magnetic induction preponderates, while in cables, when the capacity is much greater, electrostatic induction preponderates. How large an induction is allowable without rendering the use of parallel lines impossible cannot be said definitely, as this depends also on the instruments, i. e., on the strength of the currents used. If weak microphones or magneto telephones are used as transmitters, the parallel course may naturally be much greater than with powerful granular carbon microphones. It depends also on the requirements, that is, whether it is merely demanded that the cross-talk shall not interfere with conversation, or that it be impossible to understand what is said on any other wire by listening intently.

The amount of induction, however, depends not only on the inducing and the induced wires, but also on their environment. If, for instance, there are many other wires near them, the induction will be considerably weakened, for then currents are induced also in all the other wires, and these currents again produce tertiary induction currents of opposite direction to the secondary ones, weakening the latter. We thus find, strangely enough, that the induction is the smaller, the closer the wires are together, though this holds good only in case of a large number of wires. With only two wires the induction is the weaker the farther they are apart; but the dependence is not proportional, for the weakening effect increases slowly, as shown by the formula for p.

With free aërial lines the induction is noticeable on a length of 2 km. (1¼ miles), while on a route of many wires good service may be had up to 5 km. (3 miles). In some cables the induction (electrostatic) may be noticed on a length of 100 m. (328 feet), and renders good service at over 500 m. (1,640 feet) impossible, without special provisions to counteract it.

The problem of suppressing cross-talk on neighboring lines has been attacked in all possible ways, but so far only one solution of practical value has been found, the use of double wires or metallic circuit lines with no earth connection.

If four wires, 1, 1′, 2 and 2′, are on the same route and the wires 1, 1′ form one closed circuit and the wires 2, 2′ another, then a current wave in the wire 1 will induce similar waves but of opposite direction in the wires 2, 2′. The waves in the closed circuit 2, 2′ in the same direction, say from left to right, will counteract each other, so that the induction currents have no effect on the instruments at the ends of the loop 2, 2′.

But this is exactly true only when the wires 2, 2′ are equally distant from the inducing wire, as shown in figure. Otherwise the induction currents will differ somewhat — be greater in the nearer wire; hence the compensation will not be complete. If, however, the difference in distance is not great and the lines are not long, which is always the case in city exchanges, then the difference between the induction currents becomes unimportant and no troublesome cross-talk will result.

Of more importance than the exact distance between the wires is uniform insulation of the lines; for when one wire is not so well insulated as the other its induction current becomes weakened, and is thus unable to equalize the current induced in the well-insulated wire. The same effect is observed when the primary line is unevenly insulated. In that case the currents flowing in the two halves 1 and 1′ are of unequal strength and likewise those induced by them in the wires 2 and 2′, thus interfering with the compensation. Metallic circuits, therefore, give a good result only when uniformly insulated.

The same cause renders the working of a single line 3 and a metallic circuit on the same route much more difficult. With perfect insulation, the current in the single line will induce currents in the two paired wires 1, 2 of equal strength and flowing to the same end of the line, where they neutralize each other. But if the insulation of one paired wire is poor, then its induction current will partly flow to earth, losing thus its power to neutralize the induction current in the well-insulated wire, 2. With two metallic circuits the compensation remains perfect all the same, as there are not only two but four induction currents present, any two of which neutralize each other, namely, 1, 2 and 1, 2′ as well as 1′, 2 and 1′, 2′. But 1, 2 and 1′, 2 as well as 1, 2′ and 1′, 2 neutralize each other. For this reason the working of several double lines on the same route is much better than that of one double and one single line.

FREE BANKING, INSTEAD OF "FREE SILVER," AS A CURE FOR HARD TIMES.

BY AUSTIN W. WRIGHT.

It is common to hear it said that the people of the United States are at present blessed with the security that attaches to the use of "the best money we ever had." This assertion comes oftenest from those who are old enough to have been present during the time when "wild-cat" banking flourished; and by way of proof of the correctness of their views they are extremely fond of recounting personal experiences belonging to that period, and they never tire of relating that bank bills worth their face in certain localities were at a discount elsewhere, or that bills exchangeable at par one day were at a discount or worthless upon the next. Then they come down to the present, with a sweep of the hand that is intended to silence every opposing voice, and say that now, all of our money is good because it is exchangeable at par every day everywhere. It is not my purpose to point out the error of these facts; or to here show the difference between actual money and promises to pay money resting upon the belief that the money will be forthcoming when demanded; but let us first analyze the financial system which at present occupies so high a place in public esteem and see whether it is fairly entitled to the unqualified praise which it now receives.

The financial panics occurring during the past twenty-five years have been more frequent and some of them as severe as anything of the kind occurring during the "wild-cat" period. At this moment we are hopelessly groping through a depression which developed in an acute form in 1893, and not abating, has since become chronic. Wailing complaint is loud and universal, and from the length and breadth of the land comes the shriek demanding more money. Almost the entire population of the country are shouting, "Help, or we perish!" and these appeals are addressed and directed to our government because it is engaged in the banking business and is the direct, or indirect, author of all of the promises to pay money that are in circulation. Now, in the face of this existing deplorable state of things, is it not

barely possible that the present system is not what it is commonly thought to be, and that instead of being better than anything we have heretofore had, it is no improvement at all? Let us see if this much-praised governmental beneficence is not the real source and cause of all our financial ills.

It is generally conceded that more than ninety-five per cent of the business transacted nowadays is accomplished without the use of money. It is plain to every observer that the demand for money as an aid in facilitating exchanges is becoming less and less because of the increased use of credit. In these days of varied and gigantic business enterprise, it would be a physical impossibility to effect the transaction of the vast multiplicity of exchanges if people were limited solely to the use of money. In the first place, there is not in all the world money enough to do the business of the United States alone, and if there was it would not be possible to handle it. But the prime reason for the use of credit is one of expense; it is cheaper to use credit than it is to use money; time and labor are saved, and security is obtained, by the use of credit; therefore credit has almost entirely supplanted money. Now, a word in relation to our paper money; every greenback or bank bill in the United States is unavailable for business purposes except at a cost equal to its nominal face value. In so far as individuals are concerned, they are not credit money at all, and are, therefore, too expensive to be used in ordinary business and except for compulsion would not so be used. Nobody can afford to keep greenbacks, or bank bills of the present kind, constantly on hand, out of use, because they have cost too much. They represent debts consisting of services already performed for which no equivalent service has been returned; they are exactly of the same representative nature as metallic money. In order that it may be of economic efficiency, paper money must represent a credit; credit is simply the present right to demand a future payment, and the function of credit is to bring into commerce the present value of future profits. Credit can be and is bought and sold, and everything that can be bought and sold is wealth, and as about ninety-five per cent of the commerce of the United States is carried on through the agency of credit, it follows that in a comparative sense the colossal value of credit reduces the combined results of all other forms of wealth to infinitesimal proportions.

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Personal credit is a right of action which a man sells against himself and for which can be obtained either money, goods, services or other rights of action against someone else. Rights of action can be bought or sold in any form, but it is common to write them down on paper in the form of bank bills, bills of exchange, checks, drafts, etc., expressed in terms of money, in which form they become capable of manual delivery and can be passed from hand to hand like money. In this way abstract rights, without any change in nature, become material things transferable like other chattels. The promise to pay money, deliver goods, or perform service is as good as the thing promised as long as the credit of the promisor remains unimpaired. Credit rests solely upon personal character which always recognizes right and wrong and it is sustained by public confidence; public confidence is aggregated individual confidence. Character cannot be created, nor can confidence be sustained by act of Congress. It is perfectly clear that whatever impairs the value of any form of wealth must decrease the sum total of wealth, and now that it has become manifest that credit constitutes a portion of the aggregate wealth so large that the aggregated sum of all other forms put together shrink almost into nothingness by comparison, it must be self-evident that any force which limits or impairs individual credit must unfailingly act with most blighting effect upon all commercial activity.

Money is a universal equivalent exchangeable at all times, everywhere; it therefore by the very force of its character becomes nomadic; ever on the move, passing from hand to hand, going hither and thither according to the movements and desires of its owners, but always tending toward great money centers where employment for money is more constant than elsewhere.

The tendency of money toward great marts of trade is irresistible, because it is so costly that no one can afford to keep it on hand in idleness; the demand for money in small towns and agricultural communities is periodic, varying with the seasons during which crop movements occur. And this is the reason that those localities suffer from frequent periodic money stringency; and it is also the reason that interest rates are nearly always higher in those localities than at great trade centers like Chicago, New York and London. Right here is the truth in the contention of those who insist that there is not money enough with which to

transact necessary business; but the truth remains unrecognized, and therefore these people are wholly unable to indicate what would constitute proper relief. The "money sharks" of the East may be able to reap an inequitable advantage under present conditions, but they are in no wise responsible for the conditions. They in common with everybody else have been forced by law to accept the conditions and must govern themselves accordingly. Is the United States in the banking field to the exclusion of private enterprise? Do national banks enjoy monopolistic advantages conferred by law? Is the ten-per-cent tax imposed by the United States upon all promises to pay money, circulating as money, a beneficial requirement? Does not the physical power of the general government arbitrarily and completely destroy the right of the individual to use his personal credit through the agency of the local banker? Let us see.

Under present conditions, artificially established by law, the amount of money in the United States is practically rigidly fixed as to quantity; the amount required varies from day to day, and there is a further and marked periodic variation which ebbs and flows in harmony with the seed time and harvest of the principal crops, and a subvariation as to kind of crop, and latitude where grown. The United States has constituted itself into a gigantic bank of issue (the largest in the world)—hundreds of millions of dollars of greenbacks, silver certificates and treasury notes have been issued and are in circulation as money. The United States has organized national banks which are allowed to issue bank bills secured by United States bonds.

There is not in circulation in the whole United States a single bank bill or a dollar of paper money of any kind, the value of which rests upon credit. The United States occupies the field with a cumbrous costly system to the entire exclusion of private enterprise.

Is it not possible that a non-evasive act that has to be restrained by physical force might be a benefit to somebody?

We have now reached the crux of the financial trouble and the solution does not consist in an application of unlimited quantities of compulsory silver, but in *free and unlimited banking*. Banks are local, not national in character; they come into existence because of and to supply a demand incident to their environment; therefore all national laws establishing or regulating banks

[illegible] Everybody ought to be left free to [illegible] a bank whenever and wherever there should be a demand for one. There is no more danger of there being too many banks than there is that there will be too much of anything that is necessary for the growth and development of the [illegible] Bankers are simply dealers in money and credits, and there would be no more danger from bad banking than there is now from bad merchandising. Even under present conditions the sole security of people doing business with bankers consists in the integrity and intelligence of the banker. Why should the state [illegible] to fool people into belief in fancied security by expenses and hypocritical attempts at regulation? To those who still believe in the efficiency of state interference attention is directed to a still unchallenged statement which appeared some time ago in the [illegible] and which stated that no banker had [illegible] punished in the State of Illinois for fraudulent banking. And to those who say that the United States has frequently [illegible] punishment as criminal infractions of law, it might be [illegible] a managing officer of a national [illegible] violate the law. [illegible] should be pun- [illegible] the amount of [illegible] criminal penalties [illegible] state [illegible] [illegible]

conducted in accordance with sound banking principles, failure is utterly impossible, for nothing can go wrong unless the banker fails to properly perform his duties. Unlimited liability is the only natural check that is to be had against the taking of extra-hazardous risks in the conduct of the business, and it would always be inexorably operative, and therefore efficient. Natural forces are always more efficient as a corrective agency than artificial device. During 1893 165 national banks failed; these banks were located in almost every part of the United States. It is no great tax upon the memory to recall the facts in relation to those failures. In almost every case those bank failures were due to criminal mismanagement, and in many cases to actual misappropriation of the bank funds. How many of those robbers in bankers' guise were ever even brought before the bar of justice for examination as to their guilt? About banks organized under the laws of the several states, during that same period, it is unnecessary to say more than that the facts in relation to them were neither worse nor better than those relating to national banks. Yet in spite of all, most people really believe that statutory limitations and regulation are operative in a field where moral influences only are in force.

What can a banker in Chicago or New York know of the character of the man in Kansas or Texas who desires credit? or what kind of an estimate can he place on the quality of the security offered? The local banker can always form a reasonably correct opinion as to both. He is right at hand, and if left free to do so can give to every man the credit his character and security is entitled to receive, either in the form of a deposit credit or in his own bills promising to pay money at a future time. In the absence of state interference the intelligence of the banker can always be depended upon to exact sufficient security to enable him to always protect his own bills of issue. There should be no limit placed upon the banker as to amount of promissory notes which he may issue; increased demand upon the banker for the use of his credit can always be regulated and controlled by the rate of discount. And the banker can always be relied upon to protect himself by the use of the same when necessary; raising the rate as the demand increases, lowering the rate when the demand falls off. Paper money rests upon the sense of right and wrong, not upon security. Without intelligence sufficient

should be repealed at once. Everybody ought to be left free to establish and carry on a bank whenever and wherever there should be a demand for one. There is no more danger of there being too many banks than there is that there will be too much of anything that is necessary for the growth and development of the race. Bankers are simply dealers in money and credits, and there would be no more danger from bad banking than there is now from bad merchandising. Even under present conditions the sole security of people doing business with bankers consists in the integrity and intelligence of the banker. Why should the state longer try to fool people into belief in fancied security by expensive and hypocritical attempts at regulation? To those who still believe in the efficiency of state interference attention is directed to a still unchallenged statement which appeared some time ago in the Chicago *Chronicle*, and which stated that no banker had ever been punished in the State of Illinois for fraudulent banking. And to those who say that the United States has frequently administered punishment for criminal infractions of law, it might be well to say that there is not a managing officer of a national bank in the United States who does not constantly violate the law. Criminal infractions in connection with banking should be punished to the same degree as those occurring in the conduct of other lines of business. But the infliction of criminal penalties does not restore lost property. In the absence of attempted state control of banking, moral forces would have opportunity to grow and develop and the honest banker would soon drive dishonesty out of the business. Under conditions of freedom, dishonesty cannot long compete with honesty.

There should be no law limiting the liability of bankers; the state does not limit the liability of individuals in their commercial relations with each other, and bankers should not be specially favored in this respect. The sense of responsibility for every act performed should remain unimpaired; this applies with particular force to those engaged in a business in which the fortunes of others are involved. The banker performs no gratuitous service; he exacts compensation for everything he does; he should therefore assume full responsibility for his every act. He is a self-constituted conservator of common funds, for while it is true that the banker usually furnishes some capital, the real capital of a bank is always its line of deposits. So long as the bank is

[illegible]

[illegible] properly recognize and appreciate this fact, paper money [illegible] impossible. Every restriction other than natural limitations will obstruct rather than aid. No statutory requirement is necessary, obliging bankers to redeem their bank notes in money of the highest recognized standard. Competition will irresistibly impel each and every banker to provide for the immediate redemption of [illegible] promise to pay in that medium which possesses in the highest degree all the essential attributes of money, because promises so written would circulate to the exclusion of all others. Those who prefer gold would demand and invariably receive it; those who wished silver would demand and receive that. And if anything else should be deemed fit to perform the office of money, the demands of business would soon force the banker to obtain and supply what was demanded. Every banker would be governed by the consensus of business opinion in the locality where he did business and use, for redemption, the kind of money that was there deemed to be best. Or the banker could write his [illegible] to pay, making them payable in any kind of money that it [illegible] to use his bank notes demanded. These bank [illegible] would be clearing houses which would be established [illegible] each other in just the same way that [illegible] now meet and cancel each [illegible] the kind of money that [illegible] particular business and [illegible] immediately per- [illegible] Paper money has come into exist- [illegible] labor-saving [illegible] the same as that of [illegible] the avoidance of [illegible] times of large [illegible] money [illegible] the changing of the [illegible] every transaction.

[illegible] money [illegible] must, like [illegible] it must be [illegible] estimation of [illegible] possessing all [illegible] the [illegible] Paper [illegible] because [illegible] that it may [illegible] always be

regarded with the highest confidence. Confidence is a thing of growth, and in order that opportunity for growth may be had the billholder must have a chance to frequently test the ability of the author of the promise to redeem that promise. When, in the course of business, a man receives a promise to pay money, he has a right to an immediate knowledge as to whether that promise is good or not. The only way he can know is by demanding immediate payment and having the demand satisfied. Unrestricted issue would never cause redundancy, because as soon as the demand which called the notes into being was satisfied they would unfailingly return straight home to the author of their existence and demand the redemption to which they were entitled.

As soon as one of those bills was deposited in a bank other than the one issuing it the proprietor of that bank would send it home for redemption because by so doing he would not only increase his own reserve of good money but would make room for the issuance of his own promises to pay. Natural competition between bankers, each endeavoring to retire the notes of the other, would always regulate the quantity of paper money outstanding to the exact commercial requirements. There would be instant automatic response to the requirements of trade; bills would always be issued when there was a demand for them, they would be immediately and inevitably retired when the demand ceased. The volume of currency would always be in harmony with want; interest rates would be steady and nearly equal in all parts of the country; whatever variation in rates of interest there was would be due to the character of the inhabitants and the quality of security to be obtained in the localities where higher or lower rates prevailed. This money would not drift to and concentrate in money centers because it would be sustained only by a confidence inspired by a knowledge of the character of its author. Whenever it got beyond the range of the influence of that sustaining power it would be regarded with suspicion, and would therefore immediately and without fail be turned back toward home, seeking protection of its integrity at the hands of its father, the banker who issued it. Much has been said about one dollar being as good as another, and of the necessity of having paper good everywhere, but this is impossible except at an expense in excess of the cost of metallic money itself. National bank notes each cost more than their nominal face value. Credit and security

are two different things—the one costs almost nothing, the other costs whatever it is worth and is therefore expensive. None will gainsay the stupendous beneficial might of credit as an economic force, but it is impossible to enjoy the benefits of credit without accepting all of the risks incident to its nature. To those who still insist that there should be some safeguards for the billholder, in the nature of restrictions on the banker, it may be pertinent to ask what security is now afforded by law to depositors in banks, other than the honor of the banker; also upon what does the integrity of all bills of exchange now rest? Can it be justly contended that billholders have rights against bankers that are more sacred and are therefore entitled to considerations denied to all others. The fundamental principle of credit consists in the fact that it is completely dissociated from any specific sum of money. It is a pure abstract right against a person, to demand the payment of a sum of money, bought and sold on confidence and belief that the debtor can and will redeem when due. Credit does not represent specific money but is exchangeable for money. Money is capital; it therefore is clear that any economic quantity that is used in the place of money, producing the same kind of effects, may also be used as capital. Now, if a merchant can buy a stock of goods with his credit by giving a promise to pay in the future; or a contractor can exchange his credit for the services of others in the same way, it is clear that personal credit is capital in the same sense that money would be and that it can be used in all kinds of enterprise. It is scarcely necessary to explain that capital is the essential requisite to the fullest development of the resources of any country. And that in a country like the United States, abounding in undeveloped resources, almost without limit, the presence of sufficient capital to develop those resources would inaugurate such a period of industrial activity as the world has never seen. Now that it has been made plain that individual credit constitutes a capital sufficient to meet all requirements, is it not clear that what the people of this country need more than anything else is freedom to organize and put into active use their own individual credit? Of course power to use the public credit could be extended to and conferred upon individuals through governmental agencies. And schemes of that kind have been proposed by people holding communistic and socialistic belief, but the necessary machinery would have to be sustained by

increased taxation, and it would be impossible to extend such aid with the cheapness, expedition or efficiency that can be attained by private enterprise. The possibilities that such schemes would afford for official corruption and the favoritism that would most certainly ensue in the way of rewards for political preferment make any plan of that kind so wholly undesirable as not to be seriously thought of in a democratic republic. Inequality of freedom could not fail to be much greater than under present conditions and therefore more intolerable. Present conditions are the outgrowth of unjustifiable governmentalism, and so long as commercial activity and prosperity are contingent upon the state of the public credit we will be always subject to industrial paralysis constantly increasing in severity.

Most of the people who are discussing the "money question" are simply talking about the history of money. And because they cannot agree they are calling each other all sorts of bad names; differences of opinion are accounted for by impugning motives; some are called repudiationists, desiring to pay their debts in fifty-cent dollars; others are characterized as robbers, exacting two dollars for one. Now, it may sound presumptuous, but people who are giving expression to sentiments of that kind — and there are many — must either be dishonest themselves, and judging others from that standpoint, or else they do not know what they are talking about. The latter is the truth, for they certainly do not know the character of the American people. It is not so long ago that this whole people gave a five-year exhibition of honesty of conviction and sincerity of purpose — the effect seems to have been lost. Evidence of honesty ought not to be now necessary — gold advocates and silver advocates may lack wisdom, but they are not dishonest. It is possible for men to have great knowledge of the history of money, without knowing very much as to the essential requisites of money, or as to the proper functions of money. Just as it would be possible for men to have most complete knowledge of the history of governments, and at the same time have small conception of the science of government. It is quite remarkable that so few of the students of the history of money have failed to discern and recognize the fact that no people ever had any trouble in the selection and adoption, or the use, of a suitable medium of exchange, until governmental agencies inaugurated attempts to enforce the circu-

lation of debased coins by acts of legal tender. When people are left free to act in harmony with the dictates of their own intelligence there is never serious trouble, for if mistakes are made they are errors of individuals and therefore affect but few in addition to themselves. It is when the state denies the right of individuals to act, and attempts to act for them, or compel them to comply with arbitrary law in direct conflict with right, that serious trouble ensues; for it is then, and then only, that mistakes involve all and the penalty of the error is visited upon all. It is singular that these debaters, who are busy abusing each other about the history of money, have failed to note, or at least give some weight to the fact, that the use for metallic money is fast disappearing. That from a time when property rights were insecure owing to small appreciation of equity, due to lack of intelligence, all transactions were accomplished by the use of money, because under conditions of that kind the use of credit was impossible — after having passed through various stages of advancement we have arrived at the present state of development, and now, because of increased intelligence and integrity, but about five per cent of transactions are accomplished with money. Now, in face of the fact that nearly all of the exchanges of commodities are effected by the use of the varied forms of credit, what becomes of the time-honored and oft-repeated assertion that prices of commodities are governed by the ratio between the amount of commodities and the volume of actual money in use. In these modern times it is credit that raises the price of products and lowers interest rates, and whenever anything happens which impairs confidence, credit is withdrawn, prices fall, rates of interest advance; when the impairment of confidence is great we have panics the extent of which comports with the degree of impairment that confidence has suffered. Should there come a time when confidence was wholly destroyed and credit therefore ceased to exist, we would then be reduced to the use of actual money; prices would fall to merely nominal figures; the volume of business would be reduced to almost nothing; commodities would be unexchangeable; property would be annihilated; grim-visaged want would stalk through the length and breadth of the land; it would enter the homes of all, beginning with the poor who would be swept off the earth as though by a pestilence; those now well-to-do would starve; those now rich would be

pinched by hunger, provided they were permitted to live, by those less fortunate, long enough to get hungry. No tongue or pen can picture the frightful condition to which society would be reduced should there be a total destruction of credit; we of the United States are in that slough now up to our ankles, with a prospect of soon being in up to our knees. Is it not time to stop? Is it not time to turn from long-tried governmental mismanagement toward the hope and promise of individual freedom?

Jurisprudence is the science of rights. Economics is the science of the exchangeability of rights. Credit is a right of action and is exchangeable for all forms of wealth; credit is therefore wealth. The irresistible natural tendency of exchange is to conform to natural conditions, because natural conditions are always right conditions. Whenever statute law is out of harmony with the science of rights or the science of the exchangeability of those rights it inevitably obstructs or defeats the exercise of those rights. No statute law out of harmony with eternal principle can regulate, much less control, human activity. Everybody recognizes the fact that the world is too much governed — that is, that freedom of individual action is everywhere obstructed, and therefore denied. Now, in the name of all that is reasonable, why do not some, or one, of these people who have acquired a knowledge of the history of money and a knowledge of the history of governmental interference therewith, stop and think long enough to recognize the fact that coincidences are not necessarily cause and effect. That it does not follow that because governments have continually interfered with exchanges that, in so far as creative effect is concerned, that interference has had anything whatever to do with the value of the commodities or rights exchanged. That special laws out of harmony with general principles of law are responsible for all the trouble, and that our present sufferings, in relation to money affairs, are the logical effect of governmental obstruction. The cure is simple and consists in allowing a liberty of individual action, limited only by the equal freedom of each and all. The essential requisite is the instant repeal of all laws inconsistent with equal freedom. The standard of money has only to do with the quality of money and nothing whatever with its quantity. Nobody knows, or can know, how much money is required, but under conditions of freedom every people will, without fail, supply themselves with a

sufficient quantity, and of the right kind. It is clear that credit performs the same office in circulating commodities as money; that it does the work cheaper and better than it can be done with money; that it now performs ninety-five per cent of the work, and its usefulness is still growing; it is therefore absolutely essential to commercial and industrial activity and general prosperity that complete freedom to organize, exploit, and use the same be not denied.

MANUFACTURER VERSUS CENTRAL STATION.

The summer meeting of the Northwestern Electrical Association at Marinette was fairly well attended, there being thirty-two central station men and the same number of supply men present. The subjects presented for discussion were of a character interesting to the members, but the absence of the authors of the first three papers read may account for the lack of that spontaneous discussion that is usually fruitful in instructive experience. But when a general discussion followed some remarks made by Mr. Beggs, Mr. Buckley uttered a volume of wisdom in the single remark he made that the wattage of incandescent lamps was a question resting entirely with the central station men, for they are the consumers of the product of the lamp companies. The manufacturer claims that it costs from 3 cents to 5 cents more to make a 2½-watt lamp than to make a 3½-watt or 4-watt lamp — are the central station men willing to pay that extra price? Experience has shown that we could really afford to pay 12 cents to 15 cents more per lamp, but it is not wise to do so, if it means an increase in the rate we charge our customers, nor would it be advisable to accept such lamps if it meant the turning over of all our profits to the lampmaker.

Mr. John I. Beggs was frequently called on by President Baker, and his forcible and fearless remarks won the hearty admiration of the members. He said that his interest in electric lighting associations is from the standpoint of duty to those whose capital he has under his management, and to himself as a holder of investments in electric lighting plants; and in aiding to strengthen the association he strengthened himself. He scored the National Electric Light Association for its failure to seize the opportunity to place itself on record on the question of the relation of manufacturing companies to central stations, the committee appointed — and of which he was a member — never having held a single session. Yet that committee had a duty to perform that might have resulted in inestimable benefit to central station men throughout the land, in protecting them from the

encroachment of the manufacturer anxious to install a competing station. He admitted that the first seeds in such cases were generally sown by an overzealous representative, but though he had had forty-eight agents in the West, yet he defied any man to show that his office had ever attempted to exploit an opposition company, while it is on record that he had strongly and repeatedly urged the manufacturer to stand by the central station.

Mr. Beggs felt that the time had come when the central station manager should be independent of any and every manufacturer, and added the startling statement that "the two largest manufacturing combinations in the United States *are bankrupt!*" and but few of the others are in a satisfactory condition, while many electric lighting stations are returning fair dividends on their investment.

Some of the older heads felt confident that they could easily name the companies referred to. But this is doubtful. For, though the Westinghouse Company is being roasted in an Eastern journal, yet its last annual report was fairly satisfactory; a comparative analysis of the last two annual reports of the General Electric Company show a firmer, cleaner foundation than it has rested on in the past; the Fort Wayne Corporation reports a larger volume of business at better prices than it has enjoyed for months before, and is looked upon as one of the strongest and best of the manufacturing companies, while the Western Electric Company is probably financially better equipped than any other company.

But Mr. Beggs urged upon the members the advisability of pledging themselves to discriminate against any company interested in exploiting an opposition plant in the town or territory of any member of the association, clearly portraying the hesitancy with which any manufacturer would proceed if he felt confident that it would affect his future relations with sixty or seventy central stations.

So strong a suggestion might have borne fruit in some associations that would have won the respect and admiration of the leading manufacturers. But whether they will pay the slightest attention to the wishes of the average station manager in Wisconsin remains to be seen. When several members of the association gave liberally of their time and their ability to educate the representatives of the people to a correct understanding of the

relation of electric lighting companies to the public, and thus prevented the passage of oppressive measures, what response did the station men make? Did they offer to share the burden of the legitimate expenses among themselves? Or was it necessary for the supply man and the manufacturer to step in and help settle the indebtedness? Through the influence of a committee from the association, a law was passed that prevents the erection of a municipal lighting plant in Wisconsin so long as the local plant can be purchased at a reasonable price. The legitimate expenses of securing the passage of this very favorable law amounted to about $350, not counting the personal services of the committee. In response to a circular letter sent to each central station in the state, asking for a pro rata contribution of $4.19, less than one-third of the stations responded, even when a second letter was sent out by the president, and it was necessary to accept contributions from manufacturers, supply men and station men in other states to meet this indebtedness.

When discussing municipal lighting Mr. Beggs paid a compliment to Mr. Dow, now the general manager of the Edison plants in Detroit, and formerly the electrical engineer in charge of the designing, erection and operation of the municipal plant, for the systematic methods inaugurated and the careful records kept, showing that under favorable circumstances it costs the city of Detroit nearly $90 a year for each arc lamp of 2,000 candle-power.

Mr. Debell referred to some published data showing the prices charged for street lighting in an eastern city, and which was used by his town council to secure a reduction in the contract for city lighting. A careful investigation showed that the data had been incorrectly compiled, and that the city referred to was paying 4 cents an hour per lamp, while Sheboygan was paying but 2 cents per hour per lamp. And Mr. Debell felt that it was just such incomplete and garbled data, snapped up and published by so-called reputable trade papers, that is doing so much harm to central stations engaged in the street lighting business. He therefore recommended action on the president's suggestion for Secretary Mercein to gather and compile statistics showing the rates charged in each town in the state, with all the factors that may influence the rate duly entered. To aid in this work President Baker appointed a committee consisting principally of the traveling

representatives of supply and manufacturing companies to gather the data on blanks to be furnished by the association.

Mr. Beggs referred to a series of important lamp tests now being carried out by central station men: that heretofore of the three constant factors in incandescent lamps—economy, voltage and candle-power—the economy factor had been ignored, as it made little difference so long as a chemical meter and not a watt meter was employed. Now the object is to secure a lamp having a life of 300 hours, with a variation in candle-power not exceeding twenty per cent—that is, allowing the candle-power to drop to 12 ¾ before effective life has ceased. We are making a demand for a 2½-watt lamp, because we need a 20-candle-power lamp to compete with the Welsbach burner. Many are using a 4-watt lamp; to substitute a good 3-watt lamp is to increase the capacity of the station twenty-five per cent, or to be able to supply twenty-five per cent more illumination to present customers at present rates. Referring to rates, he said that in Cincinnati he sold current at 15 cents per thousand watts, which is equivalent to gas at $1.60 per thousand cubic feet; and on bills of $50 or over a discount of thirty and five per cent was allowed, which made the price the same as gas at $1 per thousand cubic feet. In this connection it is well to recall that this station is the one that Mr. Beggs was asked to straighten out some two years ago. At that time it was necessary to forward $2,000 monthly to help the station along, while at the present time it is placing $7,000 monthly on the right side of the ledger.

The people of Marinette and Menominee proved royal entertainers, and memories of the many pleasant trips by trolley lines, along the beach, in carriages to the great mills, and in yachts sailing out on the bay, will long be treasured by the participants. Thus too much praise cannot be accorded to Mr. Henry Higgins, Mr. G. W. Hanley, of Marinette, and Mr. E. Daniell, of Menominee, for the perfect arrangements that resulted in such an enjoyable convention.

FRED DE LAND.

EDITORIAL OUTLOOK.

Facts and Fancies Pertaining to the Money Question. Since the adoption by the Chicago Convention of the very radical platform proposed by the advocates of free silver, the interest in the money question has been intensified. The issue of the present political campaign seems to resolve itself into the monetary question. While not pertaining particularly to engineering, as one of the fundamental subjects of economics, the monetary question affects all industry. The natural interest in the electrical industry shown by the investing public was a rich field for the operation of the promoter. Wild-cat financiering was the order rather than the exception. Illustrious precedent and substantial support rendered by the largest corporations all have tended to produce a stagnation in electrical enterprises more severe than in almost any other line, so the possibility of a financial revolution is fraught with more than ordinary danger to this class of investments. The confusion which has arisen from the attempt of the public to alter an immutable law of nature confronts us with little short of this financial revolution.

The article in the July number on the "Unwarranted Interference of the United States in the Banking Business" contained indications of its author's solution of the question. The article in this number simply continues the previous line of argument by further advocating the discontinuance of all state and national interference in the banking business. To the ordinary person this suggestion is radical enough to seem anarchical. To the student of economics it is but the ultimate solution by natural law regardless of the acceptability of the proposition, for there will be many whose faith in paternal government will remain unshaken. The arguments advanced by Mr. Wright will be found to contain the fundamental principles on which the money question rests. These are worthy of careful investigation ere one attempts to examine the anomalies of the silver argument. It is well-nigh useless to consider the question from the basis ordinarily adopted. All admit, measured in the present exchange value, an ounce of gold is worth about thirty ounces of silver. The proposition

to have the government declare sixteen ounces of silver worth one ounce of gold and to coin all metal presented at the mints on this basis would, of course, make the value of the metal in the silver coin almost one-half that of the metal contained in the gold coin. It is evident that the government may declare these coins of equal value, but unless the metals contained in the coins possess an equal exchange value this edict or fiat will not make them equal in the markets of the world. Nor does the most earnest advocate of free silver argue that the value of these coins will be the same. Were the government able to make good this difference, both coins might circulate; but the government mints being practically thrown open to the world, an ounce of gold may be used to purchase silver at its true value, and when coined into money free of charge, by law it would become almost twice the previous amount, depending only on the fluctuations in the price of silver which this demand would make. This would very soon result in sending gold abroad, leaving practically only the silver coin in this country with the government trying to maintain a value above that which it actually possessed. There can be little question about this result, as there is a sufficient quantity of silver available to produce it.

At this point the gold man and the silver man differ. The silver man claims that owing to the scarcity of gold the present gold dollar has twice the purchasing power it formerly possessed, and therefore the depreciated dollar will have its face value, and in proof of this statement cites you a long table of commodities showing how prices have declined ever since the mints were closed to the free coinage of silver. Among these commodities which have declined in comparison to gold is silver itself; thus he states triumphantly, "It is your gold dollar which has appreciated until it is worth two hundred cents, and the producer of commodities of all kinds is forced to supply almost twice the amount he formerly did in order to obtain one dollar in gold." With various diatribes he proceeds to show how this was all brought about. If he is a careful and discerning arguer, he will take pains to omit from the table of commodities such articles of which there has been no overproduction. He will confine himself principally to wheat, because the great western valleys have been cultivated since 1873, and other countries have become large producers; the transportation systems have also been so

developed that the cost of reaching the markets of the world has been greatly reduced. He will confine himself to pig iron because the discovery of rich ore deposits, together with the increased transportation facilities and the improvements in refining, has reduced the price per ton about one-third, and in the case of steel rails to one-fifth the price they were in 1873. Cotton, too, is an excellent staple for him to confine his attention to, for near the close of the war the scarcity had made the cost of certain grades a little more than $1 per pound, while now it is less than 7 cents, and almost all grades sell for from one-half to one-third the price they brought in the market in 1873. By confining himself to commodities such as these, he will readily convince you that gold is higher and that an enormous crime or swindle has been committed in thus forcing the producer to supply from two to three times the amount of commodities he formerly did in order that he may obtain the same amount of money with which to pay off his indebtedness, or with which to purchase the necessities of life. He probably will not talk to you of pork, because in 1893 this was selling at a higher price than it was in 1873. He will probably not talk to you of bacon, coffee, and several articles of this kind, for these prices have not fluctuated and in some instances were higher in 1893 than in 1873.

Your partisan of the gold standard will pay very little attention to your table of commodities, and will sneer at your discovery that there is a close and constant relation between the price of silver and price of commodities. He will tell you that if such economic law exists it ought to apply to the price of all commodities, and while it cannot be denied that since the adoption of the gold standard the price of many commodities has fallen, just as many examples may be cited where prices have risen, and it is incontestible that wages (the price of manual labor) have risen. He will tell you to devote your attention to the improvements that have been made in the processes of production on the one hand, and in the perfecting of means of transportation on the other. He will laugh at your idea of the scarcity of gold and ask you why, if gold is so scarce and it is the only legal instrument of payment, the rate of interest and the rate of discount have both declined, for it would seem to logically follow that the rate charged for the loan of the instrument of payment should be expressed by interest and discount. He will not deny that prices

for commodities will be higher on a silver basis, but labor will be the last to feel the effects of this. The reimbursement of debts requiring fixed payment he will admit will be easier. He would probably end, however, by asking you if it is not strange that when money is so scarce and times are very hard there should be such a surplus piled up in the vaults of the banks, and stranger still that they really do not want it there. They prefer to have it in circulation and, in fact, make a lower rate in an effort to loan it. But they are apt to require very positive proof of your ability to pay it back.

Thus one is apt to inquire whether after all there may not be another question involved. Whether it is really the money scarcity that is causing the trouble, or a *want of confidence*, and when an investigation of the subject shows that for one transaction made with money there are nineteen made on confidence or credit, it appears that after all this *credit* must be an important factor, for so long as credit exists money is only used for settlements, the majority of the transactions being based upon an exchange either of commodities directly, or upon a confidence in the ability of each party to the transaction to produce either the commodities or their equivalents. Think how little money is actually handled by the business man today. His checks circulate in place of money, with no guarantee that they are good except the standing he has in the community where he is known to be a man of integrity and honesty, and no one has the least hesitancy in accepting this personal currency of his. By this means an enormous amount of business is done without handling any actual money and by means of the clearing houses; only the differences are settled in money, the checks on different banks canceling each other to a large extent. Add to this the various forms of paper such as bills of exchange, and we learn at once that the combined value of all the gold and silver in the world would be inadequate to carry on the business done if an actual transfer of money were required.

How, then, can a paper credit system be inaugurated which will be secure in the broadest sense? It is useless to cite the efforts of our government to circulate greenbacks and treasury notes and the difficulties encountered in maintaining a gold reserve to insure the redemption of this currency. The methods enforced upon the Treasury Department at present are more those

of the philanthropist than the business man. The gold reserve is thrown open to foreign encroachment without requiring the payment of an exchange rate, which any banker would require. If the present gold reserve were held by a bank, the holder of any of the notes which pass as currency would readily be accommodated with full value. If he wished an exchange on any other city he would be accommodated, but if he desired gold practically for the purpose of shipping it abroad, a bank would probably inform him that it was quoting an exchange rate, which in all probability would alter his desire. The government cannot exercise any prerogative of this kind and is consequently sacrificing its gold reserve whenever the foreign financiers require it. There is no particular demand for gold in this country, as it is used simply to insure the credit of the government. No one cares in particular to have the gold, they much prefer paper which is good. It is not the actual gold or silver, therefore, that we require, it is a paper system of credit. If the government is such a lamentable failure in the banking business, why should not its immediate retirement therefrom be a benefit?

The government credit is sustained only by its power of taxation, and repeatedly this credit has suffered so that its promises have been accepted only at a heavy discount. The banks throughout the country represent the people, they are supported by the people, and are the direct expression of the financial strength of the locality they represent. There can be no question but what the banks are far better able to maintain a currency than the government. Their very existence would depend upon the proper exercise of this function. Accepting this proposition, it is not a wild flight of fancy or imagination to follow the line of arguments and suggestions of the free banking advocate and abolish any discrimination in favor of one class of banks. The 10 per cent tax imposed upon currency issued by a bank effectually debars any but national banks issuing currency, and owing to the security required by the government, the currency issued by these banks is practically full-paid and in many instances more than full-paid. So far as the bank is concerned, there is no function of credit exercised in this transaction, as it is practically an exchange in actual money. The exercise of the 10 per cent law, on the other hand, is not a protection but a prevention. It may well be argued that the repeal of this law would place upon the

market an inflated and debased currency. But this is equally true of the checks and drafts in existence today, and no trouble is found in ascertaining their true values. The enlightenment of the public and the means for rapid communication remove, to a great extent, any hardship that might otherwise be imposed through the inability to ascertain the standing of the issuer. It is not contemplated that this system would insure any greater credit to the note of the bank than the note of the individual would possess. It is entirely a question of the standing of the bank which must be determined. A personal note would, therefore, in many cases be as good a currency as that of the bank. This is true today in many instances, as the resources of a bank oftentimes are less than those of the individual who owns the bank, the bank representing but a part of the owner's assets. With the elaborate credit system which exists today, absolutely insecure or unprotected except by the honesty of the banker, we have already a large amount of business done upon this basis, and where the scrutiny is of the individual and confidence is not extended through any implied protection afforded by the law, there is little betrayal of confidence. Notwithstanding the force of these arguments and their unquestioned applicability, the fact remains that conservatism dictates moderation. The paternalism exercised by the government has resulted in creating a dependence by removing any occasion for individual investigation, and this dependence exists among classes whose financial representatives would be apt to abuse the privilege. If this resulted in the circulation of an inflated and very much depreciated currency, restricted though it would be to very limited sections, it would nevertheless cause distrust and more or less hardship.

One must admit that the protection afforded by the law is largely implied, as witness the failures not only to protect but even to prosecute. It is almost a maxim, "If you wish to pay your debts in 50-cent dollars, make an assignment." The question is, Would stringent laws and a rigorous enforcement sufficiently protect the people and provide the necessary inducements to honesty? It may eventually be that only the fittest to survive can maintain an existence. LELAND L. SUMMERS.

RECENT PUBLICATIONS.

DIE LEHRE VON DER ELEKTRICITÄT. Von Gustav Wiedemann. Zweite, umgearbeitete und vermehrte Auflage. Braunschweig: Friedrich Vieweg und Sohn. First volume, 1893. 1,023 pages, 9 by 6; 298 illustrations and 2 tables. Paper, uncut; price 26 marks. Second volume, 1894. 1,126 pages, 9 by 6; 163 illustrations and 1 table. Paper, uncut; price 28 marks. Third volume, 1895. 1,139 pages, 9 by 6; 320 illustrations. Paper, uncut; price 28 marks.

The name Wiedemann is so familiar to physicists and electricians the world over that any introduction is superfluous in reviewing his great academic work on electricity (consisting of five volumes, three of which have appeared in their second edition, the two others announced to follow at an early date). "Lehre" is the most characteristic title that could be imagined for a work like this. The English language possesses no one word which fully expresses the meaning of "Lehre." In brief it means all that can be thought about the subject, be it by word and figure, or by demonstration. It embraces more than the theory, as it gives also the ways and means by which the theory is established and confirmed, and thus renders theory a part of "Lehre." Lessons, the English word which comes nearest to a true definition, comprises also subjects belonging to technology and thus deviates again from "Lehre." In accordance with its title throughout the work, the course of experiments, the results and a discussion of the same are given. We learn of many workers seldom heard of before, as the author may deem an experiment worth recording, even if it should be of no immediate value for investigation, for it may be useful to some future investigator. Of course, such thorough and detailed work necessitates the use of the higher mathematics; but this should not deter anyone unfamiliar with their use from enjoying the full benefit of the treatise, for the experiments, the conclusions drawn therefrom and the theory established is noted in simple language, yet some readers would not be satisfied without the mathematical proof. Maxwell had to put his mathematical seal on Faraday's doctrines before the world would accept them. Besides great mathematical ability, the writer has at his command the dead as well as the living languages of which he makes free use. On the same page may be found references to writings in three or four modern languages, and on another page to a Latin dissertation of some physicist prominent in the earlier part of this century. Though the work is physical, there is an abundance of chemical formulæ, for electricity extends its sphere day by day, and perhaps in the direction of chemistry more than in any other.

The course followed in the arrangement is historical. Frictional and galvanic electricity are treated in common. The achievements worthy of record and all literature of merit up to the year before each volume is edited, have been taken into consideration. As space does not allow of a detailed account of the contents of the three volumes, an outline of the

same may be sufficient to illustrate the scope of the treatise. The first volume begins, as could be expected, with an historical introduction, and drifts then naturally into electrostatics. The first part of this volume bearing the title "general properties of electricity," gives the development and discussion of the laws of electrostatic action, while the second part treats the generation of electricity by contact of heterogeneous bodies; this part again having two subdivisions, conductors and nonconductors. Under conductors, the fundamental laws of the galvanic current are inserted. When it comes to conductivity of bodies, the minuteness and wide-reaching scope of the work is most pronounced, as shown by the experiments upon rare metals, acids, salts, etc. With nonconductors we come to electric machines, where the Holtz machine is given prominence. The first volume concludes with diaphragm current and electric endosmose.

The second volume continues nonconductors and devotes its second larger half to electro-chemistry. The first chapter of this volume contains the dielectric constants of isotropic and anisotropic bodies, of liquids and gases, also the dielectric polarization. All through the book the author reviews without partiality the work of other physicists and states his opinion pro or contra. Whenever his own opinion differs from that of others, the why is explained and results of experiments added for corroboration. Just here the author shows an interesting point of difference between a law of Maxwell and the outcome of researches of later date. Namely, Maxwell's law regards the relation between the dielectric constant and the refraction index, i. e., $\sqrt{D} = n_\infty$, where D = dielectric constant and n_∞ = refraction index for infinitely long waves, is only approximately true for liquids and gases, while for crystals and ether it does not hold good except for sulphur.

Again and again the name of Professor Röntgen occurs. His experiments in connection with refraction and similar phenomena date back more than fifteen years, thus proving that long and profound study was required to lead to his recent discoveries. There is another incident of note, namely, that the names of Edison and Tesla appear nowhere, while American physicists of today, as Rowland and Nichols, find due regard. The last part of nonconductors is taken up by the relation between electricity and heat. First, heat and mechanical effect of the electric current are gone into, then a long chapter is devoted to thermoelectricity and changes in temperature at contact points of heterogeneous conductors, while the generation of electricity in crystals by change in temperature and pressure concludes the first half of the second volume and leaves the field to electro-chemistry.

The "Lehre" of electro-chemistry comprises six chapters, the first of which discourses the electrolysis of — well, of everything; though the reader must not expect to be told how to work a gold mine, this is an application and thus "hors du combat." The second chapter treats polarization and expands over just as wide a range as the first one did. "Change of the E. M. F. of metals by the influence of the liquids surrounding them," is the heading of the third chapter, while in the fourth we find the theory of electrolysis and the conductivity of electrolytes. Hittorf and

Ostwald, two well-known workers in this special field, have collected the bulk of material to form a theory, and deserve the highest acknowledgment, though to De la Rive, Kohlrausch, Helmholtz and others a goodly share of credit is due. After having given the theory of generation of electricity by contact of heterogeneous bodies in the fifth chapter, the author concludes the second volume by ascertaining what amount of work is done and heat given off in the electrolytic process. The results of the very elaborate experiments are recorded in tabular form, giving the observed as well as the calculated E. M. F.'s, taking the E. M. F. of the Daniell cell Zn amalg. | $ZnSO_4$ | $CuSO_4$ | Cu equal to 100 as datum of reference.

The third volume is divided in three parts: A, Electro-dynamics; B, electro-magnetism; C, magnetic properties of weak magnetic and diamagnetic bodies. Under A, Ampère's theory takes first range. For the measurement of current a thorough investigation of electro-dynamometers is made. The conclusion of this part is formed by earth currents. Electro-magnetism is a very extensive field, and perhaps the one most cultivated by practical electricians. The treatment here goes largely into details and comprises many subjects not often met with. The chapter on mutual relations between magnetism and mechanical properties of bodies is of especial interest. The last part of the third volume is of great interest, on account of its treatment of the relations between galvanic current and magnetism and light and heat; also of the relations between magnetism and dielectric polarization, chemical affinity, crystallization, cohesion and gravitation. The physicists of the hour, bent on unification and generalization, may succeed in harmonizing all physical and mechanical phenomena the same as Maxwell and Hertz harmonized electricity and light.

The study of these three volumes necessarily must fill the student with admiration and thankfulness, when he considers the immense patience and hard work that is required to study the literature of a century on the subject, and verify the theories of others; and particularly the formation of new theories by original investigation. Thus it is the duty of us "Jünger der Kunst" to try and add leaves to the laurel wreaths that crown already the heads of our masters.

F. J. DOMMERQUE, M.E.

ELECTRIC LIGHTING.—A practical exposition of the art for the use of engineers, students and others interested in the installation or operation of electrical plants. Volume I. The Generating Plant. By Francis B. Crocker. New York: D. Van Nostrand Company, 1896. 444 pages, 6½ by 9½; 151 illustrations; price $3.

In electric lighting, Professor Crocker has endeavored to present the electrical engineers with an encyclopedia of the construction of electric lighting plants. The volume in hand deals particularly with auxiliary apparatus, such as the buildings, boilers, engines, etc., which form the necessary, though what might be termed external organs of a lighting plant. From the preface the reader infers that the gist of the subject is to be found in the succeeding volume. Professor Crocker always aims at a lofty mark, and in attempting to present a compendium of electric lighting he has gathered an armful of science that embraces all engineering practice.

While for lucidity and brevity it is almost impossible to criticise the volume, so necessarily severe compression has been exercised upon the great variety of topics exhibited that the reader, unless already quite familiar with the subjects considered, must seek sources of knowledge that are sufficiently more diluted as to permit of easier assimilation. To an educated engineer of considerable experience, the volume forms a valuable reference work, placing him in touch with the latest state of the art. Altogether, the central station manager and engineer can scarcely afford to miss this work from his library, and the concluding volume will be anxiously expected. The typography and presswork correspond with the usual excellence exhibited by these well-known publishers. A. V. ABBOTT, C.E.

MESURES ÉLECTRIQUES. Par Eric Gerard. Paris: Gauthier-Villars et fils, Quai des Grands-Augustins, 55, 1896. 457 pages, 6½ by 9½; 198 illustrations.

In England and America electrical progress has been chiefly from the practical standpoint of introducing this most wonderful form of energy to useful application in the arts. In France and in Germany more attention has been given to the investigation of electrical theory. To electricians, the name of Eric Gerard is correlative with one of the most valuable works on electrical science. Forsaking pure theory, Professor Gerard in the present volume has embraced the most complete published collection of the methods of making electrical measurements of all kinds. The introductory chapter deals particularly with general measurement methods, and a discussion of the most favorable conditions under which measurements may be made; the determination of the probable error, with directions for interpolation and the graphic representation of results. Succeeding this chapter is one upon the methods of estimating geometrical and mechanical magnitudes, in which the reader will find a description of the most approved laboratory instruments for such investigations. Photometric tests form the topic of the third chapter. In chapters four and five, electrical measurements, pure and simple, are introduced, and deal chiefly with standard instruments. In chapters six and seven, galvanometers and the methods of making current determination are exhibited at length, while chapters eleven and twelve deal with the estimation of potential. Chapters thirteen and fourteen are occupied with resistance and capacity, chapter fifteen, with energy measurements, while chapter eighteen is devoted to inductance. The remainder of the volume is particularly interesting to the engineer, as it elucidates all of the best methods for making measurements upon electrical plants in actual operation. Transformers, accumulators, motors and dynamos are successively treated, and the various methods of investigating their performance being succinctly developed. The sections upon the testing of transmission lines form valuable and novel reading, as there is, perhaps, no other work that contains so great an amount of matter upon this important branch of electrical engineering. The volume closes with a number of valuable tables. The practicing engineer will look far to find a more encyclopedic collection, or a more lucid presentation of the methods of measurements. A. V. ABBOTT, C.E.

Electrical Engineering

SEPTEMBER, 1896.

QUESTIONS AND ANSWERS RELATING TO PATENTS.

BY CHARLES A. BROWN.

Q. 1. What is a patent for an invention?

A. A patent for an invention in the United States is the exclusive privilege granted by the government to make, use or sell an invention. This grant is evidenced by letters patent issued under the seal of the Patent Office and signed by the Commisssioner of Patents and the Secretary of the Interior. The grant is made under the patent statutes of the United States which have been enacted pursuant to the authority of the Constitution, which says: "Congress shall have power to promote the progress of science and useful arts by securing, for limited times, to authors and inventors the exclusive right to their respective writings and discoveries." (Const. U. S. Art. I, Sec. 8.) Congress has fixed the length of this exclusive period at seventeen years.

A patent may be looked at as a contract between the government acting for the people of the United States and the inventor. The consideration given by the inventor is the disclosure of his invention, so that one skilled in the art to which it pertains may understand and practice it. This disclosure is embodied in the specification of a patent including the drawings. The consideration given by the government is the right to prevent others from making, using and selling the invention for the period of seventeen years, which exclusive right the government undertakes to maintain and enforce through its courts and administrative machinery.

Q. 2. How is a patent obtained?

A. Anyone, whether a citizen of this country or not, may

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obtain a patent if he is the original and first inventor of "any new and useful art, machine, manufacture or composition of matter or any new and useful improvement thereof, not known or used by others in this country, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, and not in public use or on sale for more than two years prior to his application, unless the same is proved to have been abandoned." (Revised Statutes, Sec. 4886.)

The applicant must describe his invention in such full, clear and concise language as will enable those skilled in the art to which his invention relates to practice his invention. This description, together with the drawing illustrating his invention, if it be a machine to manufacture, an art or a design, and also with a specification of the precise claims which limit and define the bounds of his invention, should be sent to the Commissioner of Patents, at Washington, with a fee of $15, which is known as the "first government fee."

The rules of procedure in presenting and prosecuting the application for a patent are quite technical and are set forth in a pamphlet of upward of one hundred pages, issued by the United States Patent Office for gratuitous distribution.

Briefly, the course of the ordinary application for a patent in the office is as follows: After the application has been forwarded in due form with the prescribed oath and all other details correctly attended to, the applicant receives notice of the receipt of the application with the information as to the serial number which is given to the application. Some weeks, or even months, subsequently, depending upon the condition of the work in the department to which the application is referred, the applicant receives the first official action. If the invention is properly described and the claims are of proper form, the Patent Office will allow such claims as are not anticipated by descriptions of the invention set forth in any one of the claims in some prior patent or publication. It then becomes the duty of the applicant or his attorney to so amend the claims as to avoid these references, and this may result in protracted correspondence between the applicant or his attorney and the Patent Office before an agreement is reached setting up the boundary line between the invention claimed by the applicant and what is known as the "prior art"— that is, all

that was known to those skilled in the art prior to the date of the invention by the applicant. When this agreement is finally reached, notice of allowance of the patent is sent out by the Patent Office, which calls for the "final government fee" of $20, which must be paid within six months from the date of the allowance. The patent will then issue on the third Tuesday following the Thursday upon or before which payment of the final fee at the Patent Office is recorded, and the patent is sent to the applicant or to his attorney.

Q. 3. For what may a patent be obtained?

A. A patent may be obtained for "any new and useful art, machine, manufacture or composition of matter, or any new and useful improvement thereof." A patent may also be obtained for any new and original design for "a manufacture, bust, statue, *alto-relievo* or *bas-relief;* any new and original design for the printing of woolen, silk, cotton or other fabric; any new and original impression, ornament, pattern, print or picture to be printed, painted, cast or otherwise placed on or worked into any article of manufacture; or any new and useful shape or configuration of any article of manufacture," under the conditions described in the statutes.

Design patents referred to above are granted for three years and six months, or for seven years, or for fourteen years, the government fee being $10 for a three-years-and-six-months' design patent, $15 for seven-year, and $30 for a fourteen-year design patent. The fees above mentioned are all that are required in case of a design patent.

By far the greater number of patents granted by the office are for an art, machine, manufacture or composition of matter, and of these four classes by far the largest number of patents are granted for machines.

An art, process or method patent, as it is variously called, is generally considered more desirable when the claim is skillfully drawn and when the invention permits of it, on account of the breadth of the claim. The celebrated first telephone patent was a patent on the art of telephonic communication. When, however, the process is such that it relates to the manufacture of an article and the product resulting from the process may be transported, there is danger that a process patent may not protect the invention, for the process may be employed in

foreign countries and the resulting product be shipped into this country without any infringement of the process patent. This very fate befell an important patent relating to the process of dyeing. The process described in the patent was employed upon fabrics manufactured in Switzerland and other foreign countries and transported to this country. It was held by the court that there was no infringement of the process by the introduction into this country of the product resulting from the process practiced abroad.

Q. 4. May a patent be obtained if the invention has been in use prior to the application?

A. Yes, if the invention has not been in public use or on sale in the United States for more than two years prior to his application an inventor may secure a valid patent therefor. The public use of an invention in other countries than the United States for any length of time does not bar the grant of a United States patent. The question whether or not an invention has been in public use for more than two years prior to the application, when brought to the attention of the Patent Office, may be determined before the grant of the patent by public use proceedings instituted by the Office.

Q. 5. Suppose two persons make the same invention and apply for patents thereon, which one is entitled to the patent?

A. The patent is granted to the one who first made the invention. The question which one of two applicants for a patent upon the same invention first made the invention is determined in the Patent Office by what are known as "interference proceedings." An interference is in the nature of a suit in equity, and evidence is taken for the respective part[illegible] [illegible]dance with the rules prescribed for taking testim[illegible] [illegible]quity suits in the United States Courts. It is the [illegible] [illegible] Patent Office in carrying out the law to grant the [illegible] the one who first put his invention in condition to be [illegible] of to the public. This is in pursuance of the polic[illegible] [illegible] Law to grant the monopoly of his invention to th[illegible] [illegible] to the public the information which enables [illegible] [illegible]rt to practice the invention. The general [illegible] who was first to conceive the invention [illegible] shall be given the patent, provided [illegible] [illegible] the invention to practice, or in appl[illegible] [illegible] doing both.

It should be noted that the one who makes his invention outside of the United States, whether he be a citizen of the United States or a foreigner, is at a disadvantage with one who makes the invention in the United States, for the date of the invention which can be claimed for one who made the invention abroad cannot be prior to the introduction of the knowledge of the invention in the United States, or prior to the date of the publication of a description of the invention or to the issue of a patent for the invention abroad.

The questions decided by an interference proceeding in the Patent Office are often of great importance, and settle the questions of the titles to valuable inventions. An interference may be declared between two pending applications which claim the same invention, or between an unexpired patent and an application claiming the same invention, and in certain other cases, as particularly set out in the Rules of Practice of the United States Patent Office. The rules governing the conduct of interference proceedings are contained in the Rules of Practice referred to.

There is also a provision in the Statutes of the United States, Section 4,918, which enables the patentees of two conflicting patents to have their respective claims decided by the United States courts by a suit in equity. This proceeding may be resorted to when two patents for the same invention have been issued by the Patent Office by a mistake without declaring an interference, or after an interference in the Patent Office between an application and an unexpired patent.

The determination of the question of the priority of invention between two or more parties to an interference proceeding is decided first by the Examiner of Interferences, from whose decision upon the question of priority there is an appeal to the Board of Examiners-in-Chief. An appeal from the decision of the Board of Examiners-in-Chief can be had to the Commissioner of Patents, and, finally, an appeal from the decision of the Commissioner of Patents to the Circuit Court of Appeals for the District of Columbia.

Q. 6. If an application for a patent is wrongly rejected, what remedy has the applicant?

A. When the Primary Examiner to whom the application for a patent is referred, rejects an application or any claim or claims of an application which the applicant or his attorney thinks the

[illegible] appeal may be taken from the decision [illegible] examiner to the Board of Examiners-in-Chief [illegible] question is argued ex parte although the [illegible] may present a written argument in support of his [illegible] application. From the Board of Examiners-in-Chief [illegible] an appeal may be taken to the Commissioner of [illegible] if the Board of Examiners decides adversely to [illegible] of the applicant and finally the applicant has an [illegible] to the Court of Appeals.

[illegible] an application for a patent enable the inventor to [illegible] manufacture or sale of his invention?

[illegible] Not until the grant of the patent is made by [illegible] of the government will a suit lie to prevent [illegible] use or sale of the invention described or claimed [illegible] The life of the patent under ordinary conditions [illegible] years and it dates from the date of issue of the [illegible] It has no effect prior to the date of issue any more than [illegible] to the date of its expiration. Articles embodying [illegible] of the patent, however, may not be used or [illegible] the date of the issue of the patent, even if made prior [illegible] of the issue for the use or sale of the patented invention [illegible] constitutes an infringement of the patent, just the same as [illegible] of the invention does.

This however is subject to the limitation that Section 4,899 [illegible] Revised Statutes provides that one who purchases of the [illegible] or with his knowledge and consent constructs any newly [illegible] machine or other patentable article prior to the application for a patent shall have the right to use the specific thing so made or purchased without liability therefor.

Q. 8. Does a patent give the patentee a license to make, use and sell the patented invention without regard to other patents?

A. It does not. A misunderstanding of this fact is a source of much error on the part of inventors, and of much unreasonable criticism of the patent law. The grant of a patent gives the patentee the exclusive right to make, use or sell, or to license others to make, use or sell the invention described and claimed in the patent. The invention described and claimed may be a very narrow one in an art which is already broadly covered by other patents; for example, there were hundreds of patents upon details of construction of telephones and upon various forms of

telephones which were issued during the life of the broad patent granted to Bell upon the telephonic art. Of course, the subsidiary and narrow subsequent patents gave no license to use the prior fundamental patent granted to Bell. So it may be in any art. A patent may be granted for some improvement upon an invention which is already broadly covered. The improvement may not be used by the one who has the broad fundamental patent any more than the broad invention may be made use of by the subsequent patentee of the improvement.

Q. 9. What is a caveat?

A. "A caveat under the Patent Law is a notice given to the Patent Office of the caveator's claim as inventor, in order to prevent the grant of a patent to another person for the same alleged invention upon an application filed during the life of a caveat without notice to the caveator.

"Any citizen of the United States who has made a new invention or discovery, and desires further time to mature the same may, on payment of a fee of $10, file in the Patent Office a caveat, setting forth the design thereof, and the distinguishing characteristics of the invention, and praying protection of his right until he shall have matured his invention. Such caveat shall be filed in the confidential archives of the office and preserved in secrecy, and shall be operative for the term of one year from the date of filing thereof.

"The caveat may be renewed on request in writing by the Patent Office, by the payment of a second fee of $10, and it will continue in force for one year from the date of the payment of such second fee. Subsequent renewals may be made with like effect.

"An alien has the same privilege if he has resided in the United States one year next preceding the filing of his caveat, and has made oath of his intention to become a citizen.

"The caveat must comprise a specification, oath, and, when the nature of the case admits of it, a drawing, and, like an application for a patent, must be limited to a single invention or improvement." (Rules of Practice, 197-201.)

While there are cases where a caveat is of advantage, these cases are extremely rare, and the filing of a caveat is not generally advised. In fact, in some instances, the filing of a caveat is a distinct disadvantage; thus, it has been said that if

Elisha Gray, on February 14, 1876, had filed an application for a patent instead of a caveat, which he did file, he, instead of Bell, might have been entitled to be considered the inventor of the telephone.

Q. 10. May a patent be extended or renewed?

A. Theoretically, it may; practically, no. Up to the year 1861 the duration of a patent was fourteen years, with the privilege of extension under certain conditions for seven years additional. The important patents under this law were ordinarily extended. By the Act of 1861, the term of a patent was made seventeen years, and patents may not be extended except by special act of Congress, and after that by reference to the Commissioner, who will determine in accordance with prescribed rules, whether the patentee is justly entitled to the extension.

Under this law, although there have been special acts of Congress referring to the question of the Commissioner, no patentee has secured an extension of his patent.

Q. 11. Upon what grounds will a patent be declared invalid by the court?

A. In special cases, as where fraud in the procurement of letters patent is shown, a patent may be declared invalid by the courts in a direct proceeding brought by the United States government to secure the annulment of the letters patent. Such an attempt has been made, so far without success, in connection with the original Bell patent, and such an attempt is also being made in connection with the Berliner patent. A proceeding of this kind, however, is only maintained in cases where facts are set up which could not be set up in defense of a suit for infringement upon the patent.

The statute provides the following defenses for suits for infringement of patents:

First. That for the purpose of deceiving the public the description and specification filed by the patentee in the Patent Office was made to contain less than the whole truth relative to his invention or discovery, or more than is necessary to produce the desired effect; or,

Second, that he had surreptitiously or unjustly obtained the patent for that which was in fact invented by another, who was using reasonable diligence in adapting and perfecting the same; or,

Third, that it had been patented or described in some printed publication prior to his supposed invention or discovery thereof; or,

Fourth, that he was not the original and first inventor or discoverer of any material and substantial part of the thing patented; or,

Fifth, that it had been in public use or on sale in this country for more than two years before his application for a patent, or had been abandoned to the public.

The usual defenses in suits for infringement of patents are, first, that the patent is invalid because anticipated by some prior patent, publication or use of the invention before the date of the application for the patent; and, second, that the claim of the patent is not infringed by the defendant's device or process.

Q. 12. How does a patentee secure protection from the courts?

A. The almost universal procedure in enforcing the monopoly granted to the patentee is to bring a suit in equity asking for an injunction to prevent the further making, using or selling of the patented invention, and also for an accounting for the damages to the complainant and the profits to the defendant secured by the alleged infringing, making, using or selling of the patented invention. This is under Section 4,921 of the Revised Statutes:

SECTION 4,921. The several courts vested with jurisdiction of cases arising under the patent laws shall have power to grant injunctions according to the course and principles of courts of equity, to prevent the violation of any right secured by patent, on such terms as the court may deem reasonable; and upon a decree being rendered in any such case for an infringement, the complainant shall be entitled to recover, in addition to the profits to be accounted for by the defendant, the damages the complainant has sustained thereby; and the court shall assess the same or cause the same to be assessed under its direction. And the court shall have the same power to increase such damages, in its discretion, as is given to increase the damages found by verdicts in actions in the nature of actions of trespass upon the case.

An action at law may be resorted to to secure damages for past infringement and this is the only remedy to which a patentee has recourse after the expiration of a patent, for a court of equity secures jurisdiction of a patent suit only for the purpose of preventing the continued infringement. The award of damages and profits which may be made by a court of equity is incidental to the relief by injunction. But, after a patent has expired, an injunction can no longer be secured, and hence the jurisdiction of a court of equity falls.

Q. 13. Is the marking of a device made under a patent with the number and date of the patent essential?

A. Section 4,900 of the Revised Statutes provides as follows:

SEC. 4,900. It shall be the duty of all patentees, and their assigns and legal representatives, and of all persons making or vending any patented article for or under them, to give sufficient notice to the public that the same is patented; either by fixing thereon the word "patented," together with the day and year the patent was granted; or when, from the character of the article, this cannot be done, by fixing to it, or to the package wherein one or more of them is inclosed, a label containing the like notice; and in any suit for infringement, by the party failing so to mark, no damages shall be recovered by the plaintiff, except on proof that the defendant was duly notified of the infringement, and continued, after such notice, to make, use or vend the article so patented.

It will be seen from the above that the failure to mark the patented device in accordance with the requirements of the statute will prevent the securing of damages except on proof that the defendant was duly notified of the infringement and continued after such notice to make, use or vend the article so patented. The failure to give notification of the patent as provided by the statute does not, however, interfere with the right of the patentee to an injunction.

It should be noted also that there is provision in Section 4,901 for punishing by a penalty of $100 for each offense one who in any manner marks upon anything made, used or sold by him for which he has not obtained a patent the word "patent" or any word of like import for the purpose of deceiving the public or for the purpose of counterfeiting the mark of the patentee.

Q. 14. Does the mark "patent applied for" afford protection against infringement?

A. It does not. This mark, which is frequently put upon articles, is presumably intended to have a moral rather than a legal effect. It is not required by statute, and, of course, does not answer the requirement of the statute as to marking the patented device after the issue of the patent.

Q. 15. What is a reissue patent and how is it obtained?

A. A reissue of a patent is granted to correct defects in the original patent. It is granted when the original patent is inoperative or invalid, or for any important defect arising through "inadvertence, accident, or mistake, and without any fraudulent or deceptive intention." A reissue is obtained by surrendering the original patent and making a proper showing as to the reasons for a reissue. The reissue patent expires seventeen years from the grant of the original patent, and the application for a

reissue should be made within two years from the grant of the original patent.

Until the decision of Miller *vs.* Brass Company, in 1881, it was common practice to take out a patent with carelessly drawn claims with the intention of reissuing the patent later with claims that were drawn upon devices which might appear in the market and which might be held to come within the scope of the invention.

The animadversion of the Supreme Court of the United States in the Miller *vs.* Brass decision put an end to this practice. Reissues now are in practice only taken out in case of inadvertence, accident or mistake and the claims are not now, as was the former practice, broadened in the reissue.

Q. 16. What effect does a foreign patent to the same inventor have upon a patent subsequently issued in the United States for the same invention?

A. The United States patent in such a case will expire with the foreign patent, and if more than one foreign patent is taken out it will expire with the one having the shortest term. For example, if a patentee in the United States takes out a British patent prior to the date of his American patent, his American patent will run for less than fourteen years, fourteen years being the life of the British patent, and will expire with the British patent. This is in accordance with Section 4,887 of the United States Revised Statutes, which is as follows:

SEC. 4,887. No person shall be debarred from receiving a patent for his invention or discovery, nor shall any patent be declared invalid by reason of its having been first patented or caused to be patented in a foreign country, unless the same has been introduced into public use in the United States for more than two years prior to the application. But every patent granted for an invention which has been previously patented in a foreign country shall be so limited as to expire at the same time with the foreign patent, or, if there be more than one, at the same time with the one having the shortest term, and in no case shall it be in force more than seventeen years.

This is a section of the statutes which has given rise to much controversy of late. It is now settled that the expiration of the foreign patent on account of the failure to pay the annuities which are required to keep a foreign patent alive is not such an expiration as carries with it the expiration of the American patent. The American patent is limited by the potential life of the foreign

patent under the conditions mentioned — that is, if a foreign patent might have been extended for fifteen years, the fact that it expired at the end of three years will not determine the life of the American patent. It is also settled that if a foreign patent to the same inventor and for the same invention expires prior to the date of application for the American patent, then the American patent, if issued, becomes void.

It is also settled that it is the sealing or issuing of the foreign patent, and not the lodging of the specification, which determines whether or not the foreign patent was "patented in a foreign country," and thus limits the life of the American patent. It is also settled that it is the date of issuance of the American patent, and not the date of application for the American patent, which is the crucial date. Any foreign patent to the same inventor and for the same invention which is sealed prior to the issue of the American patent, comes within the requirements of Section 4,887, and limits the life of the American patent as therein set forth.

These views of this section of the statutes as finally approved by the Supreme Court, were those almost universally accepted by patent lawyers from the first. Recently, however, in view of the great value attaching to patents which came within the provisions of this law, certain eminent counsel, stimulated no doubt by large retainers, have made a vigorous effort to induce the Supreme Court to legislate the plain provisions of the statute out of existence.

THE MANUFACTURE OF WIRE.*

BY FREDERIC A. C. PERRINE, D.Sc.

(*Continued from page 127, Vol. VII.*)

While hard-drawn copper wire is immediately applicable to the construction of transmission lines after it has been subjected to the wire-drawing process described, iron and steel are found to be too readily oxidizable for such employment; consequently before wires made of this material can be used in the construction of transmission lines it is necessary that they should be protected against the destructive action of the atmosphere. The earliest method put into practice for the protection of iron wire consisted in soaking the coil in a bath of boiled linseed oil. This covering was not found to be as durable or as cheap as that produced by a method of coating which has more recently been used exclusively, called *galvanization.* The galvanizing of iron wire consists in coating the wire with a layer of zinc strong enough to prevent the action of atmospheric corrosives upon the iron itself. This process is performed after the wire has been subjected to all of the processes included under the head of the general term "wire drawing."

Before galvanizing can be performed, it is necessary that the wire should be carefully freed from scale, and therefore an annealed wire must be subjected to the cleaning process before it can be galvanized, though hard wires are immediately ready for galvanizing after they come from the wire-drawing block. In whatever manner their surface may be prepared, wires to be galvanized are thrown in coils upon a set of "swifts" which are arranged in open order of lines behind the zinc baths, so that the wires may be drawn from them independently. From these swifts the wires are unreeled and carried together, first through a bath of chloride of zinc containing a small percentage of free hydrochloric acid and thence through a tank of molten zinc which is kept at the temperature necessary for galvanization by a fire located beneath it. As the wires come through the zinc bath they are finished either by carefully wiping off as much zinc as possible with

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asbestos wipers, or when a large coating of zinc is required on wires which are to be subject to the action of the elements, they are simply passed through a bank of sand lying upon the molten zinc, which strips back only the larger drops of loosely adherent metal. Cooling is performed in the first case by plunging the wire immediately into water as it leaves the wipers; while in the second case the wire is cooled simply by a long passage through the air before being reeled up.

The product of these two operations are different both in character of surface and continuity of zinc. The first described produces that which is called "wiped galvanized wire"; the coating is capable of affording only a slight protection against the action of the elements, though the surface obtained is as smooth as that of the original surface of the wire. The quantity of zinc thus taken up by the wire amounts to about two per cent of the original weight of the wire. The coating is not perfectly continuous, but is as flexible as the original wire, and it is therefore used exclusively when some operation such as weaving must be performed. The other process to the product of which the term "galvanized wire" is applied without qualification produces the wire which is used on our telegraph lines or for the armor of submarine cables and affords the best protection we can obtain for bare iron wire suspended out of doors. The added weight of the zinc amounts to as much as from five to seven per cent of the original weight of the wire, though it is the custom to draw the wire for galvanization slightly smaller than the standard size of the bare iron wire, so that the completed wire differs but little in either diameter or weight from the bare iron wire of the same gauge number. Since wiped galvanized iron wire is slightly cheaper to manufacture than the standard galvanized wire the greatest care must be taken not to confuse these two products, and where wire is intended for suspension out of doors the standard test for the quality of galvanization should invariably be applied. This test consists in the immersion of the wire which has been galvanized in a saturated solution of sulphate of copper for one minute, then after removal the wire is to be wiped dry and the same operation repeated four times. If the galvanization has been complete no change other than a slight blackening of the surface of the zinc will be noticed, but if the galvanization is not complete, copper is immediately deposited upon the exposed iron

by the means of the strong local action between the zinc of the covering and the iron of the wire. The opposite error of excessive galvanization may be detected by the breaks in the zinc when the wire has been wound around its own diameter.

Galvanized wires such as we have described are used mainly in the construction of short telegraph lines, for guy wires, for pressure wires on constant potential circuits, for guard wires in electric railroad construction, and for trolley suspenders in electric railroads where poles along the sides of the street are employed. When great conducting power must be obtained, iron is not so economical as copper, since iron wire is rarely less than one-third the price of copper wire of the same size, while the conductivity of the copper wire is about seven times the conductivity of the best qualities of iron.

Solid copper wires are used in the construction of aërial lines until the size of wire required exceeds .46 inch. When a wire of this size is employed, the greatest length of a single coil that can be produced without joint in any of our existing wire mills is about three hundred feet, and not only does this short length require many and expensive joints on the line, but also wires of such great diameter are likely to become considerably deformed by being repeatedly wound upon wire blocks or reels. The difficulty experienced in removing all bends from heavy wire while it is being strung is also very great, and in consequence conductors of great size may be more satisfactorily constructed by building up smaller wires into the form of a strand. Wire strands are built up of a number of layers of small wires twisted one upon the other, the wires in each layer being laid parallel, and the layers crossing each other on account of the direction of their twist being reversed. Strands are divided into perfect and imperfect strands according as the constituent wires all touch each other or are laid with open spaces between them. The perfect strands being confined to those having a center of either one or three wires. Two or four wires afford centers which may be reasonably included in this class, though the construction does not absolutely conform to our definition ; a larger number of wires for the center of a strand, however, clearly belongs to the imperfect class, and should not be used for the reason that they do not give a round section unless wires varying in size are employed. In any strand the various layers lay perfectly round each other when the number of wires

in each successive strand increases by six, except in the case of the first layer laid around a one-wire center, which allows only a total of seven wires, including the center and the first layer above it. Accepting two or four wire strands as perfect, we find that the perfect strands are laid according to the following table :

NUMBER OF LAYERS.	NUMBER OF WIRES IN STRAND.							
	One-wire center.		Two-wire center.		Three-wire center.		Four-wire center.	
	Per layer.	Total.	Per layer.	Total.	Per layer.	Total.	Per layer.	Total.
1	1	1	2	2	3	3	4	4
2	6	7	8	10	9	12	10	14
3.....	12	19	14	24	15	27	16	30
4.....	18	37	20	44	21	48	22	52
5.....	24	61	26	70	27	75	28	80
6.....	30	91	32	102	33	108	34	114
7.....	36	127	38	140	39	147	40	154

Strands composed of more than seven layers as described in this table can only be laid with great difficulty, for the reason that few, if any, of the cable manufacturers are equipped with machines capable of laying more than forty wires at one time, which is the number in the seventh layer of the four-wire strand.

Where a very great flexibility is desired, this property may be obtained either by making the strand of a great number of small wires, or by twisting a number of strands together into a rope, the latter construction having the defect that the exterior surface is not cylindrical in form, but the rope in section is composed of a series of intersecting circles having sharply reëntrant angles.

The sizes of different conductors may be distinguished by reference either to the measurement of their diameters expressed in mils, in fractions of an inch, or in millimeters, but the custom of wire manufacturers has rendered the distinction of wire sizes by reference to certain gauge numbers much more common. These gauge numbers are all more or less arbitrary and are a relic of the time when the correct measurement of a wire diameter was not readily made and when wire drawing was performed with great lack of uniformity. In order to compare various wires recourse was had to gauges of different forms upon which

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numbers were stamped corresponding to different sizes determined arbitrarily, and as the business has been developed the old gauge numbers have been expressed in decimals of an inch or in millimeters, and certain new gauge numbers have been adopted in which the variation in sizes of the different wires follow particular laws. The gauges above referred to were, in the earliest practice, plates of metal through which holes had been bored corresponding to the different sizes of wires. (Fig. 1.) Many disadvantages attach themselves to this method of gauging. In the first place, it is necessary to square the end of the wire before determining its size; secondly, any irregularities in cutting off the wire would lead to false results in gauging, and finally it is impossible to tell whether the wire is closely or only roughly a fit into its particular hole. The first advance upon this method was made by the introduction of a gauge formed of a circular plate of metal with slots corresponding to the different gauge numbers sawn into its edge. (Fig. 2.) This gauge was capable of being used upon any part of the wire and of determining with greater accuracy the variation of the wire from its true gauge number.

In about 1850 a new gauge was introduced which gave not only the gauge number, but with a reasonable approximation the variation of any particular wire from its gauge number. This gauge (Fig. 3) consisted of two straight edges of metal clamped together in such a manner that an open "V" was inclosed by their straight edges, and along the sides of one or both of these edges straight lines were stamped corresponding to the different gauge numbers. In use the wire of which one wished to determine the size was slipped into the "V" until it firmly touched both sides, when the nearest line would determine its size, and the distance from that line would determine the variation from the true gauge number. Although these different gauges have been manufactured from time to time most carefully of hardened steel and ground with great accuracy they were subject to variations in size, produced by changes of temperature, and were especially liable to wear when frequently used upon a particular size of wire, thus introducing considerable confusion when wires were ordered to correspond to one instrument and manufactured from another, though both may have been identical when they were originally constructed. In consequence,

these gauges have been and are at present used only for approximately determining the size that a wire is intended to be, but they cannot be constructed as instruments for determining the exact diameter of any wire. For ascertaining this quantity we now make use of measuring calipers (Fig. 4), which may be in the form of a sliding rule or more commonly in the form of a screw vise (Fig. 5), the thread of the screw being accurately cut and the number of turns or fractions of a turn indicated upon the stem of the screw.

While the accurate determination of the size of any particular wire can only be made by some form of micrometer caliper, gauge numbers have a distinct advantage in enabling manufacturers to carry stocks of wires and allowing purchasers to choose for their use sizes of wire which may be obtained with reasonable promptness. The earliest gauge numbers were those adopted by different manufacturers, each wire drawer having his own sizes which were not respected by any other manufacturer, and even in many cases carefully avoided by his competitors, in order that each man's product might have its own individuality.

The first effort toward uniformity was made by the wire manufacturers around Birmingham, England, who adopted a set of gauge numbers called the "Old English Wire Gauge" which was subsequently changed to the Birmingham Wire Gauge. This Birmingham wire gauge formed the basis for most of the gauge numbers adopted by the American wire manufacturers with certain minor changes introduced by individual manufacturers, and up to the year 1857 this system continued with its consequent confusion and variations of size. During that year the Association of Brass Wire and Sheet Manufacturers requested the firm of Brown & Sharpe to make a number of "V" gauges numbered according to the Birmingham system which they intended to adopt as their standard. In constructing this gauge it was at once seen by the Brown & Sharpe Company that there was a great lack of uniformity in the variations between the different sizes and numbers used in this system, and consequently Brown & Sharpe recommended to the association that they adopt a gauge the numbers of which would correspond to areas varying in geometrical progression. The advantage of such a system was at once seen by the brass manufacturers and the gauge then proposed was adopted by them. Since that time the wisdom of the

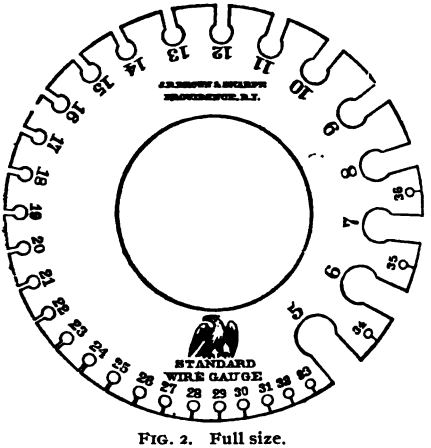


FIG. 2. Full size.

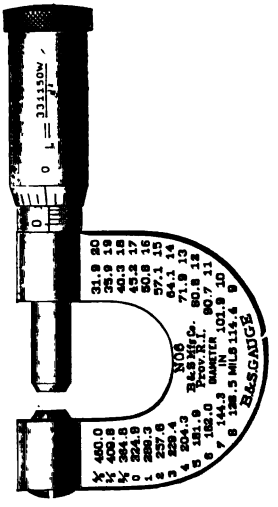


FIG. 5.

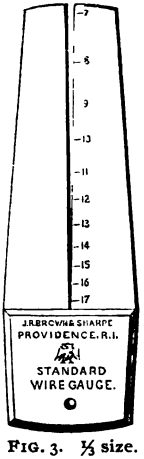
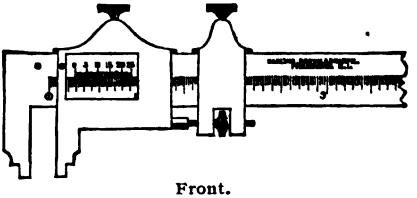
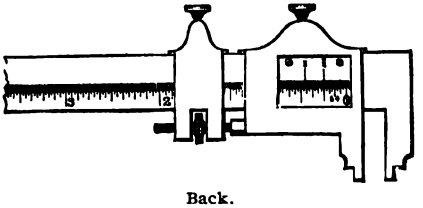


FIG. 3. ⅓ size.



Front.

FIG. 4 Half size.



Back.

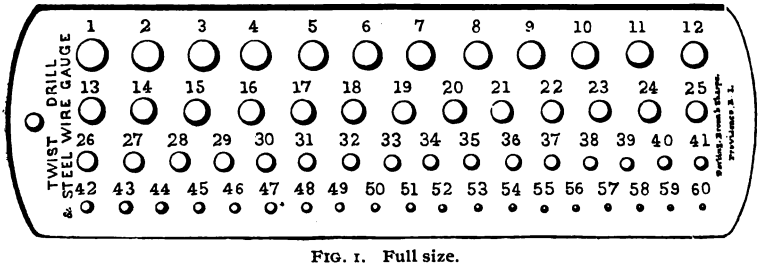


FIG. 1. Full size.

change has been proved throughout its continued use, especially for the users of electrical conductors, in which service the carrying capacity of the wire varying as the area is the most important point to be determined. A new gauge is now adopted as the standard in England and is called the English legal standard or Imperial wire gauge. This gauge differs from the American, or B. & S. gauge, in not determining the gauge numbers from areas, but in merely being a correction of the Birmingham gauge in such a manner that the variation in the size of the various numbers proceeds uniformly. In Fig. 6 is shown the comparative sizes corresponding to the numbers of these three gauges.

Of recent attempts to change the system of numbering wire gauges the most notable is that adopted some years ago by the Edison Company, in which the gauge numbers refer to the areas of the wires in circular mils, the different numbers representing even thousands of circular mils; the system embodying very considerable advantages with the sole disadvantage that its identification with one company has hindered its general introduction. At the present time there seems to be no reason for desiring any change from the common system used in the determination of wire sizes unless it would be possible to eliminate altogether the Birmingham wire gauge from use and to introduce in this country both for iron and copper wires the more rational American gauge which is the standard for the users of electrical conductors who are by far the largest purchasers of wire at the present time. This wire gauge begins with No. 0000, having a size of 460 mils, and ends with No. 40, 3.14 mils in diameter. Larger conductors than this No. 0000, as we have already said, cannot readily be manufactured or handled, and in consequence the sizes of conductors with a greater area are generally expressed by their areas in circular mils and are almost always built up of smaller wires twisted into the form of a strand. In order to determine the size of the wire for forming any strand of a particular number of wires it is necessary only to divide the area of the strand by the number of wires, which will give the area of the constituent wires of the strand in circular mils, and the extraction of the square root will determine the diameter of the wires in mils; and conversely, the area of a strand in circular mils may be found by multiplying the square of the diameter of its constituent wires, expressed in mils, by the number of wires in the strand.

(*To be continued.*)

TELEPHONE CABLES.

BY DR. V. WEITLISBACH, OF BERNE, SWITZERLAND.

1.—Talking Through Cables.

In telephony we deal only with cables carrying many wires, say 50 or 100 or more pairs. In ordinary grounded-circuit cables each copper wire is enveloped by a nonconductor and a large number of such wires formed into a cable. In talking over such a cable a strong overhearing is observed. As elsewhere explained, the overhearing may be due to three different causes, electro-magnetic induction, electrostatic induction and leakage. Cables are used mostly for short distances only, and in this case the electro-magnetic induction is small compared to the electrostatic induction, on account of the great capacity. The leakage will be great or small, depending on the insulation. Leakage and electrostatic induction, however, have a remarkable relation to each other, for if the cable is not perfectly insulated a part of the charging current, instead of flowing through the end of the cable to ground, leaks through the insulating substance. Hence the charging currents observed at the end of the cable fall as the insulation decreases, so that cables only tolerably insulated give less cross-talk than those perfectly insulated. But as soon as the insulation drops below a certain point, the leakage takes the upper hand and cross-talk increases rapidly. In general the cross-talk on ordinary cables of about 500 m. (1,640 feet) length is so great as to prevent simultaneous use of several wires in the same cable. Besides the cross-talk there is another drawback — much poorer transmission, the voice showing far more distortion than on air lines. The cause of this phenomenon is the retardation in the cable. This is the most important point in the use of cables in telephony, and must therefore be treated fully.

Electric waves propagated through a conductor are influenced in two ways; on the one side their amplitude, on the other side their phase is changed, this change depending in a

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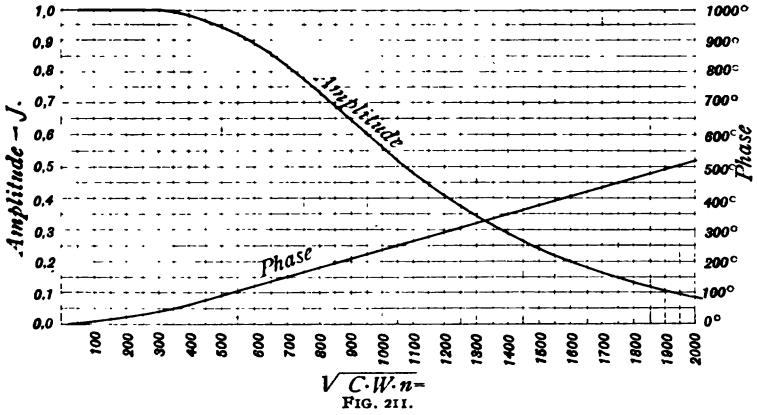

FIG. 211.

very perceptible manner on the frequency of the waves and on the pitch of the tone. Electric circuits generally are conditioned by four different qualities: resistance, insulation, capacity and self-induction. As will be shown later on, the rôle of insulation and self-induction is so slight in good cables as to leave only the resistance and capacity worthy of consideration; and thus the current strength comes to be a function of resistance, capacity and frequency — a function of the product of these three quantities.

In Fig. 211 the form of this function is represented by a curve. The unit chosen is the current in a line, for which the capacity $C = 0$, i. e., in an aërial line. In the same manner the curve of the phases is plotted.

To explain the meaning of the curves and at the same time to illustrate the character of the retardation, a concrete case will be treated.

A formerly much-used cable has a copper conductor of 0.7 mm. (.028 inch) diameter, 50 ohms resistance per km. (80 ohms per mile) and a capacity of 0.24 microfarad per km. (0.384 per mile). Required the lengths which diminish by one-half the amplitudes of the current for the waves having the frequencies 100, 500, 1,000 and 2,000 per second. The curve in Fig. 211 shows that the amplitude at the end of the cable still amounts to one-half of that at the beginning of the cable if $\sqrt{n C W} = 1.088$.

Calculating from this the corresponding cable lengths for the different pitches, we obtain for a tone with

300 vibrations, a cable of 33 km. (20.6 miles)
500 vibrations, " " 14 km. (8¾ miles)
1,000 vibrations, " " 10 km. (6¼ miles)
2,000 vibrations, " " 7.4 km. (4⅝ miles)

This table shows the great influence of frequency upon the weakening of the tone, but perhaps the following table, giving a comparison of the weakening effects of tones of different pitch for different lengths of cable, will illustrate the point still more clearly. The table shows the amplitudes at the end of the cable only, and the amplitude for $C = 0$ is assumed as unit.

Vibrations.	1 km. (⅝ mile.)	5 km. (3⅛ miles.)	10 km. (6¼ miles.)	15 km. (9⅜ miles.)	20 km. (12½ miles)	50 km. (31¼ miles)
100	1.00	1.00	0.99	0.95	0.87	0.19
500	1.00	0.98	0.81	0.50	0.27	0.00
1000	1.00	0.94	0.54	0.22	0.08	0.00
2000	1.00	0.81	0.27	0.07	0.01	0.00

This influence of frequency must be put in the foreground for the reason that it is the principal element which determines the length of the cable over which conversation can be carried on. As stated in the introductory chapter on waves, the sounds of human speech are composed of a greater or less number of simple harmonic waves, and the sounds are characterized by the following three moments:

1. The pitch of the fundamental tone.
2. The number of the accompanying harmonic overtones.
3. The intensity of these different overtones.

Selecting from the table there given the vowel *a*, observe how its partial tones are changed in transmission through a telephone cable of a given length. It is to be remembered that the intensity or energy of vibration (electric or acoustic) is in proportion to the

Length of Cable.	PARTIAL TONES.								
	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
0 km	1.00	0.88	0.91	1.84	1.37	1.80	2.11	0.05	0.40
1 "	1.00	0.88	0.91	1.84	1.37	1.80	2 10	0.05	0.39
5 "	0.98	0.81	0.77	1.38	0.89	1.03	1.02	0.02	0.12
10 "	0.75	0.36	0.20	0.23	0.09	0.08	0.06	0.00	0.00
15 "	.0.35	0.08	0.03	0.02	0.00	0.00	0.00	0.00	0.00

square of the amplitude and the square of the number of vibrations. Hence the intensities of the partial tones must be multiplied by the squares of the factors obtained from the curve. The above table gives the values of the intensities of the different partial tones of the vowel *a* for 1, 5, 10 and 15 km. length of the cable mentioned.

A length of 1 km. leaves the intensity of the partial tones nearly unchanged, while with a length of 5 km. the higher partial tones are already materially weakened; with a length of 10 km. the intensity of the fundamental tone is still ¾ of its original value, while the high partial tones disappear entirely; with a length of 15 km. the intensity of the fundamental tone drops to 1-10 of its original value.

Hence the conclusion may be drawn that through 1 km. of the cable in question conversation will be very good, through 5 km. pretty good, while through 10 km. it will be difficult and through 15 km. impossible to understand.

As the effect of distortion depends on the product of capacity and resistance, with a different cable having, for instance, only one-half the capacity, conversation is possible through a greater length. Let $A \div C \times R = l^2$. CR to be the value of the product, which is fixed by experience at about 500, in accordance with the above calculation, then the length through which, under normal circumstances, conversation can be carried on, is

$$l = \sqrt{\frac{A}{CR}} = \frac{22}{\sqrt{CR}}$$

This figure, of course, is a rough approximation only, and is intended merely to give an idea of the influence of the cable on telephonic transmission. With very perfect instruments communication is feasible over somewhat greater lengths, but since besides the cables a good many other elements, such as aërial lines, drops, bells, etc., go to make up the circuit, all tending to weaken speech still further, the above figure must be considered a maximum, and, according to circumstances — the kind of instrument used, the switching apparatus, the length of the circuit, etc. — a lower value must be taken to attain satisfactory results. Various authorities have given vastly different rules, which are really of no value to the engineer.

The number of vibrations (frequency) affects not only the

amplitude, but also the phase of the wave. Its value as a function of the product $C\ W$ (or $K\ R$) is also shown in Fig. 211. The effect of phase distortion is to break down the exact definition of successive sounds, the quicker-moving higher partial tones of the new sound coinciding with the slow-moving low tones of the previous one. In the length of 10 km. of the cable mentioned, the retardation at different frequencies will have the following values:

For.....	100	....	500	....	1000	....	2000	vibrations.
Retardation	680	....	680	....	570	....	460	millionths of a second.

The differences of retardation which alone have to be considered are so small that only with high tones is speech perceptibly affected; with low tones not at all. The effect may be largely overcome by talking slowly and with an evenly modulated voice.

As mentioned before, the value A, which determines the length of cable through which good conversation is possible, depends on different factors, and it is to be expected that various authorities will give different rules. We put $A = 500$, while Preece assumes 4,700 or 12,000 per mile, but he makes no distinction between air lines and underground cables nor between single lines and metallic circuits.

2.—*Cable Construction.*

Having examined the difficulties to be met with in cable telephony, the question is how to overcome them as far as possible by proper construction. We will consider first the attempts to overcome cross-talk, and then the means employed to reduce the retardation.

A. Cross-Talk.—The best remedy for cross-talk is a metallic circuit. Instead of grounding both ends the circuit is made complete, the wires being twisted spirally about each other. A current in a third neighboring wire will then induce simultaneously currents of equal strength in both wires of the pair, but of opposite polarity and neutralizing each other at the ends of the line.

Such loops are virtually free of induction and any number of them may be combined in a cable without showing any trace of cross-talk.

The only condition is that the insulation of the cable shall be uniform throughout so as not to weaken the charging currents by leakage more at one point of the cable than at another, for this would unbalance the currents.

Metallic-circuit cables cannot be used with single-wire plants, which are consequently being transformed or changed to permit the use of metallic circuits.

Cables for single lines have been made as follows:

Between the conductors intervenes an electrical screen in the form of a metal tube of thin tinfoil or copper ribbon enveloping the insulated wire. The static charge and the induction currents then flow in this tube and pass harmless away to the earth. On a third outside conductor only a very small differential effect can be exerted. It is essential that the screen shall offer to the induced currents a quick and easy path to the ground. For this purpose thick copper wires are sometimes introduced between the tinfoil covered strands and grounded at both ends, remaining in contact with the tinfoil envelopes throughout the cable.

Experience teaches that the more numerous the parallel wires the less the cross-talk. With only two wires in a cable it is so strong that the listener may be in doubt as to which wire the talking is on. As the number grows the cross-talk decreases. Any given wire is subject not only to the induction effect of the talking wire, but also to that of all other neighboring wires with their induced currents opposed to the primary one.

There is thus a differential effect between the primary and secondary induced currents, and the balance of induction becomes the weaker the more wires are bunched in a cable. Assuming that all the conductors of a large cable (with fifty or more wires) are grounded at both ends, the cross-talk on lengths of less than 1 km. (5/8 mile) is no stronger than on overhead lines. To reduce it still further a thick wire has sometimes been placed in the center, and then with a thick lead covering the compensation currents become comparatively strong. Such cables have the advantage of considerably lower capacity than those with tinfoil, say about 0.1 mfd. per km. A much-used cable of this type was the original Patterson cable with paraffin insulation, made as follows: The wires were first double cotton-covered, then twisted into a core and the whole again wound with cotton. After drying out at a temperature of about 80° Cent., the cable was drawn into lead pipes and then filled with hot aërated paraffin. The cables were originally pulled into shorter pieces of pipe and these afterward soldered together. The liquid paraffin was kept under a pressure of 5 to 8 atmospheres and mixed with carbonic acid gas.

RETARDATION.

The difficulties encountered from retardation are greater than from cross-talk. As previously explained, retardation is a consequence of the condenser effect between the conductor and its environment. This effect is twofold, namely:

(1) The electrostatic charge of the condenser, one coating of which is formed by the conductor and the other by the metallic bodies in its vicinity (tinfoil, lead covering, copper wires). This part of the effect is determined by the geometrical proportions of the wire.

(2) The electrical polarization of the intervening insulating materials. In order to explain the condenser effect of two conductors, we must assume that in some way the electrical energy is transferred from one conductor to the other through the intervening insulating material, whereby the dielectric itself becomes sympathetic or, as it is termed, is polarized. This polarization of electric forces can be compared to the magnetization of a piece of iron by magnetic forces. According to the nature of the dielectric the energy is transmitted more or less perfectly and more or less quickly, and correspondingly the condenser charge will move more or less quickly. In the one case the charge will keep pace with the electro-motive force, in the other it will lag behind. Very often the dielectric remains polarized after the electro-motive force has ceased. This phenomenon has its counterpart in residual magnetism. Cables, whose insulating material possessed this property, are said to have a residual charge, which consists in current flowing out of the cable for some time after the electro-motive force has disappeared. Insulating materials showing a slow or even a residual polarization are not suitable for telephone cables, as the current curve is thus altered and speech distorted.

The less the polarization the better the material for the purpose.

The capacity of a cable conductor of the length l (in km.), radius r of the copper wire and radius R of the insulation, is approximately:

$$C = \frac{1}{2}\, l \frac{k}{\log_\varepsilon \frac{R}{r}} = 0.217\, l \frac{k}{\log \frac{R}{r}}$$

k being the specific induction constant.

The following table contains the values of the induction constants for the more important materials in use for cable insulation. Air, manila paper, paraffin, ozokerite, oil of turpentine and resin have the smallest constants, and thus are the best for telephone cables, while the materials used in telegraph cables, as gutta-percha and vulcanized rubber, are less favorable. Besides a high induction constant, gutta-percha and rubber present a considerable residual polarization and a very high time constant. It always takes some minutes, and in long cables sometimes hours, before the polarization attains its maximum.

Electrization is much quicker at a low than at a high temperature. At a high temperature the insulation resistance of all known materials decreases, but this depends so much on their treatment that it is impossible to arrive at exact figures.

TABLE OF SPECIFIC INDUCTION CONSTANTS.

MATERIAL.	CONSTANT.	AUTHORITY.
Air under a pressure of 1 mm. of mercury.	0.94	Ayrton.
Hydrogen under a pressure of 760 mm. of mercury	0.9997	Boltzmann.
Carbonic acid under a pressure of 760 mm. of mercury	1.000356	"
Air under pressure of 760 mm. of mercury	1.	Standard.
Clear paraffin	1.92	Boltzmann.
Clear paraffin	2.32	"
Vulcanized caoutchouc	2.94	Schiller.
Pure caoutchouc	2.34	"
Resin	2.55	"
Ebonite	2.56	"
Ebonite	3.15	Boltzmann.
Sulphur	3.	Wüllner.
Shellac	3.84	Boltzmann.
Gutta-percha	4.2	"
Mica	5.	"
Flint glass, very light	6.57	Hopkinson.
Flint glass, very heavy	10.1	"
Ozokerite	2.	
Oil of turpentine	2.	
Olive oil and oil of hoofs (neat's-foot oil)	3.	
Manila paper	1.5	

The best insulating material is without doubt dry air. In the Fortin-Hermann cable this fact was well utilized. In order to keep the copper wires a certain distance apart small thin beads of wood soaked in paraffin are drawn over them, forming, so to speak, a chain of many links. The conductors are then bunched

and twisted and finally drawn into a lead pipe. The dry air forms the dielectric. Of course, the cable must be air-tight.

Each insulated wire has a diameter of over 4 mm. (0.16 inch), too thick for a cable of many conductors.

The American process is therefore preferable. Each wire is wound with one or two layers of manila paper in narrow strips. In order to hold air these strips are sometimes indented or perforated. The insulated wires are cabled and then covered with lead pipe after drying out, then again dried out and tested, and finally the ends are filled with paraffin for about a meter. These cables have a capacity of about 0.045 to 0.050 mfd. per km. (0.075 to 0.080 mfd. per mile).

The dielectric constant is no smaller than that of cotton, but the paper retains more air about the copper wire and is less hygroscopic. Paper insulated cables are therefore the easiest to manufacture and their insulation remains good for the longest time. They are now almost exclusively used in telephony.

Besides the properties of the insulating material the dimensions of the cable influence the retardation materially. The latter, as already mentioned, is a function of the product of resistance into capacity. Let r be the radius of the wire and R the radius of the insulating material, then the product

$$C\,W = 0.217\, l \frac{k}{\log \frac{R}{r}}\, l \frac{c}{\pi r^2}$$

The smaller this product the less the retardation. By taking a thick wire the resistance can be made very small, but then the radius of the insulating material must be increased at the same time, else the capacity rises and we thus lose the gain. But this makes the cable more expensive, and as a rule the conductor is not carried beyond 1 mm. (0.040 inch) in diameter. As the capacity decreases but slowly in a logarithmic proportion to the diameter of the insulating material, the reduction of the capacity by increasing the thickness of insulation has an economical limit, which is ordinarily fixed by the requirements of good insulation and easy mechanical construction.

In discussing cross-talk it was shown that metallic circuits obviate it entirely. Happily the same remedy can be applied to reduce retardation to a minimum, the condenser effect being thus prevented almost entirely. If we select on the metallic line two

neighboring sections of the length L, having a capacity C as regards their common metallic envelope, and let V be the electric potential at the respective point of cross section, then the electricity bound by the conductor 1 is

$$e_1 = -\frac{d V_1}{d t} C$$

In conductor 2 the potential will be equally great, but as the current flows in the opposite direction, the bound electricity is

$$e_2 = +\frac{d V_1}{d t} C$$

The sum of these quantities is zero, and no electricity at all is bound or held. Such a cable behaves just as if its capacity were zero. However, the capacity of both wires is never exactly the same, neither will the current and potential be equally great at all parallel points of the circuit on account of current loss and leakage, so that the effect of capacity will still be felt on long metallic lines though much less than on grounded lines. It is the smaller the less the distance between the two wires of the pair.

Another feature of telephoning on metallic circuits is phase distortion. The velocity of propagation of an electric wave in a cable is determined by the formula

$$v = 2\sqrt{\frac{n\pi}{CW}} = \sqrt{\frac{2m}{CW}}$$

The velocity thus depends again on the product of capacity into resistance, and besides this — and this is most important — on the frequency or number of vibrations m. For the older American conference cable with a resistance of 22 ohms per km. $\left[= 22 \times 10^9 \left(\frac{cm}{\text{sec}}\right)\right] dm$, a capacity of 0.05 microfarads per km. $\left[= 0.05 \times 10^{-15} \left(\frac{\text{sec}^2}{cm}\right)\right]$ we get for different frequencies m the following velocities v

$m =$	10	100	1,000	5,000
$v =$	4,250 km.	13,500 km.	42,600 km.	95,300 km.

per second.

THE AIR-DRYING PROCESS FOR TELEPHONE CABLES.

BY DR. V. WIETLISBACH, OF BERNE, SWITZERLAND.

Principles of the Process.— Cables insulated with paper or cotton retain their insulation only when the lead covering remains absolutely impervious. The entrance of moisture renders them unfit for service. This is a great inconvenience, for it is difficult to prevent accidents to the lead covering. Repairs are costly and the interruption of the service still more serious.

The air-drying process remedies this trouble by permitting repairs to be easily made and without interrupting the service. Furthermore, the splicing, always a delicate operation by the ordinary methods, is made very simple by the use of the air-drying process, which has now been adopted throughout France for dry core cables, both telephonic and telegraphic.

Method.— The core of the cable, including the splices, remains free of insulating compounds, such as paraffin, resin, etc., so as to afford free passage for the air from one end to the other after laying.

In splicing, no special precautions need be taken to keep out moisture, which will be carried off by the dry air passed through the cable after splicing and connecting to the terminals. Thus the splicing can be done more rapidly, and with economy of time not only in splicing but also in testing the insulation of each conductor after each splice, instead of which it suffices to bunch the conductors and see that they are free from contacts. Moreover, while it often happens that paraffined splices show a low insulation and must be remade, the insulation during splicing may now be disregarded. The greater portion of the cables laid in France are spliced in this way, and have never caused any trouble.

But the principal advantage of the method is the facility of repairing faults caused by accidents to cables already in service. As soon as a cable becomes faulty from perforation of the lead and the consequent entrance of humidity, dry air is sent

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into it from both ends in order to force the humidity out at the hole where it entered. After a few hours the insulation will have risen sufficiently to permit the normal use of the cable.

Dry air is continuously sent into the cable from both ends, until the original insulation is reëstablished. The minimum insulation admitted in France is 1,000 megohms per kilometer. There only remains to solder up the hole in the lead covering and the repairs are complete, having been effected without using new material and with no interruption whatever to the service. The hole to be repaired is easily located by the compressed air used for the drying, which produces, as it issues, a characteristic whistling noise, especially in the case of small punctures which would be most difficult to locate by any other method.

In order to facilitate the finding of the fault, it is well to make an electric test by the loop method, by which it may be very closely located. This test can be made immediately after the dry air has been started into the cable — that is before the insulation has risen at all.

In one case a 50-pair cable 1,600 m. long, serving 49 subscribers, became faulty owing to the entrance of moisture at a badly soldered splice, the insulation of the conductors having fallen to 500 ohms per kilometer. Dry air was at once sent into the cable from both ends. Three hours later the insulation had risen to 100,000 ohms per kilometer and good service was restored. In forty-eight hours the insulation was 4,000 megohms per kilometer and the defective splice had been repaired, without depriving any subscriber of the use of his telephone during the operation. The splice might have been repaired more quickly, but it was holiday time and workmen could not be had at once. This detail is worth noting, as showing that the final repairs may be postponed when for any reason workmen cannot be had immediately.

Plant.— The plant may be set up at or near the central office and comprises apparatus for drying the air, with a pressure regulator, an air compressor with a motor for driving it, and a reservoir.

Air-drying Apparatus.— The air-drying apparatus consists of several iron pipes, each about one meter high and 20 cm. in diameter, connected in series. Inside each and about 20 cm. from the bottom is placed a thin iron plate pierced by numerous holes, the space above the plate (about 80 cm. high) being filled with cal-

cined chloride of calcium. Each pipe rests on a couple of wooden blocks, and a small faucet screwed in the bottom of each permits the water which gathers there to be drawn off.

In the last pipe of the series, just in front of the final exit of the air, is placed a wad of ordinary cotton about 30 cm. thick, which filters the air and prevents any chloride of calcium dust from passing into the cable.

Finally each pipe is joined to the one next in series, by tubes so connected as to be easily dismounted. This form of air drier has given excellent results.

The number of pipes must be sufficient to insure perfectly dry air at the exit—six of the above dimensions have been found ample—and their diameter must be sufficient to insure a slow movement of the air through the chloride of calcium, so as to absorb all humidity. To make sure from time to time that the air which has been passed through the drying apparatus contains no moisture, it is simply necessary to pass some of it through a carefully weighed bottle of sulphuric acid. The acid shows no increase in weight after the passage of the air, if the apparatus is working properly.

Regulator.—Air taken directly from a system of public distribution of compressed air is generally at too high a pressure to be directly applied to the drying out of cables. It is therefore necessary in such cases to put a regulator on the air-drying apparatus. The regulator employed at the central office in Paris is not extremely sensitive, but it costs little, is simple and solid, and is probably preferable, for this use, to a more exact or delicate instrument. It consists of a valve controlled by a lever on which articulates a piston rod, the lower end of which communicates with the air tube between the drying apparatus and the cable. The maximum pressure is fixed by means of a weight, consisting of lead rings adjustable on the lever. As soon as the pressure on the end of the piston raises the weight, the valve closes, thus preventing the pressure in the drying apparatus, and therefore in the cable, from exceeding the maximum at which the regulator is set.

Distribution of Dry Air.—To dry out the splices during the laying, dry air is sent through the cable from the central office end. A 28-pair cable, 8 kilometers long, was spliced after this method, and no difficulty was experienced in sending the air from

one end to the other with a pressure of one atmosphere at the central office end.

In repairing faults the air should be sent into the cable from both ends simultaneously, as before stated, in order that the humidity at the fault be not forced to pass through parts of the cable which are perfectly good, thus slowing up the operation. This condition is not indispensable, but is of great utility. Means of distributing dry air from other points than the central office should therefore be provided. Lead pipes 3 mm. thick and about 50 mm. in diameter are generally used, being branched from the larger pipe at the drying apparatus. Each important cable route should be provided with a lead pipe, with small valves for taking off dry air let into it at the starting and terminal points of cables.

On less important routes a cable may be used as an air-pipe, the passage of the air being of course slower than through a special pipe, but as the necessity for its use arises very rarely — perhaps never, with a first-class conduit system — the slight inconvenience may be disregarded.

Attachments on the Cables.— In connecting cables to terminals there is generally a fall of insulation in both, dependent on their type and the care used in the work. But on passing a current of dry air through the terminal by means of a small hole made for this purpose, the insulation rapidly rises.

Cable terminals should be perfectly air-tight, but they are never tight enough to support without some leakage the pressure necessary to force air through the cable. This difficulty is easily remedied in the following manner: Before the cable is put into the terminal, the lead covering is taken off about 60 cm. from the end for a length of about 30 cm. A lead sleeve, in which has been fixed a small brass inlet, is soldered over the place thus laid bare. By means of a funnel, applied to this inlet, boiling paraffin is poured into the sleeve and thence into the cable end, which is meanwhile held lower than the point at which the paraffin enters. The paraffin penetrates between the conductors and stops up the cable on the terminal side of the sleeve. In order to saturate the cable it is only necessary to heat it slightly by a common lamp at the point where the paraffin is introduced. Then when it becomes necessary to dry out the cable for any reason it is only

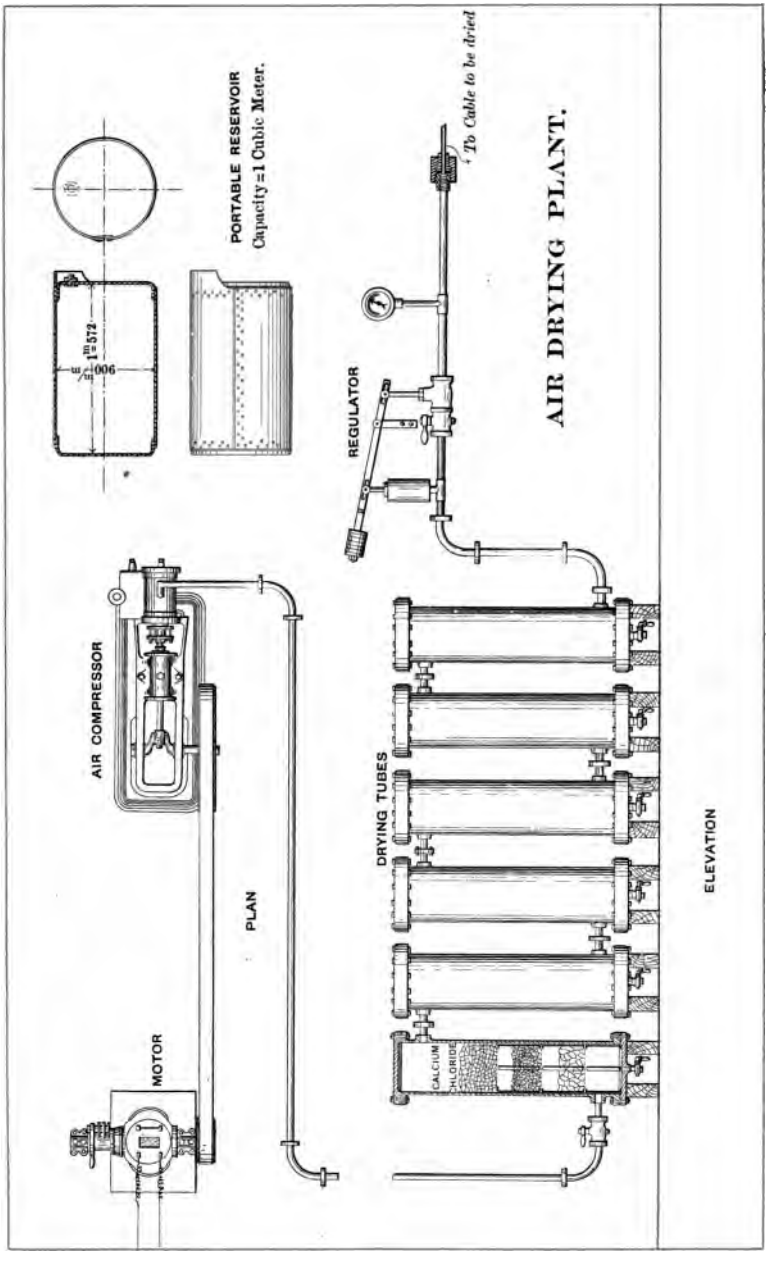

FIG. 212.—SCALE ABOUT $\frac{1}{60}$.

necessary to connect the dry-air tube to the brass inlet on the lead sleeve, which is easily done by a rubber hose.

It is also practicable to charge portable reservoirs with compressed dry air at the air-drying station, and send them to distant places where the quantity of cable to be laid does not warrant the laying down of a special plant. Such portable reservoirs may be drum-shaped, with faucet for charging and discharging the air. At six atmospheres pressure, a reservoir of one cubic meter will of course hold six cubic meters of air, sufficient to dry out one kilometer of 100-pair cable under ordinary circumstances.

Pump and Reservoir.—In Paris the plant consists of the air-drying apparatus and a system of distribution, the compressed air being furnished by the pipes of the Popp system. At Lyons and at Marseilles it was necessary to fit up an air compressor with a reservoir. As steam was to be had at the various central offices in these cities, the type of compressor chosen was the Westinghouse, as employed on locomotives for the air brake. These air compressors are too well known to require any description. They were chosen in spite of their relatively low efficiency because of their great strength and compactness. They are provided with a regulator which shuts off the steam as soon as the pressure in the reservoir has reached the desired point.

The dimensions of the reservoir may vary with the importance of the plant. For a central office of 6,000 subscribers a reservoir containing two cubic meters at atmospheric pressure is sufficient. It should be provided with a safety valve, which is usually set at five atmospheres. A detailed description of the reservoir is unnecessary, as its form may be varied at will.

If no steam is to be had, the air compressor may be run by a gas or electric motor.

The drawing shows the plan of a complete plant for furnishing air for drying cables. The air compressor is shown as run by an electric motor. (Fig. 212.)

ELEMENTS OF COMPLEX QUANTITIES AND VECTORS WITH REFERENCE TO THEIR USE IN ALTERNATING CURRENT WORK.*

BY FRANZ J. DOMMERQUE, M. E.

Sine Series.—If we put in MacLaurin's series $f(x) = \sin x$,

$f'(x)$ becomes $\cos x$

$f''(x)$ becomes $-\sin x$

$f'''(x)$ becomes $-\cos x$

$f''''(x)$ becomes $\sin x$

. . . . . .

Now, when $x = 0$ in these expressions, we have

$f(x)_0 = \sin 0 = 0$

$f'(x)_0 = \cos 0 = 1$

$f''(x)_0 = -\sin 0 = 0$

$f'''(x)_0 = -\cos 0 = -1$

$f''''(x)_0 = \sin 0 = 0$

. . . . . .

hence

$$\sin x = 0 + x + 0 - \frac{x^3}{1 \times 2 \times 3} + 0 + \frac{x^5}{1 \times 2 \times 3 \times 4 \times 5}$$

$$- \frac{x^7}{1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7} \cdots\cdots\cdots$$

$$= \frac{x}{1} - \frac{x^3}{1 \times 2 \times 3} + \frac{x^5}{1 \times 2 \times 3 \times 4 \times 5}$$

$$- \frac{x^7}{1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7} \cdots\cdots\cdots \quad (106)$$

As the last factor of the denominator of the nth term equals $2n - 1$ and the last factor of the $(n - 1)^{st}$ term equals $2n - 3$, the ratio of the two last terms will be

$$\frac{x^{2n-1}}{1 \times 2 \times 3 \times \ldots (2n-3)(2n-2)(2n-1)} : \frac{x^{2n-3}}{1 \times 2 \times 3 \times \ldots (2n-3)}$$

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[illegible]

[illegible] will be less than [illegible] and consequently the series will be convergent. But [illegible] cannot exceed [illegible] or [illegible] hence placing [illegible] the inequation [illegible] or [illegible] or [illegible] must be smaller than unity in order to make the series convergent.

[illegible] In the present instance we give to [illegible] the value [illegible] and thus

[illegible] = sin [illegible]

[illegible] = [illegible] cos [illegible]

[illegible] = sin [illegible]

[illegible] = cos [illegible]

[illegible]

Hence, putting [illegible] we write

[illegible] = cos 0 = 1

[illegible] = sin 0 = 0

[illegible] = − cos 0 = − 1

[illegible] = sin 0 = 0

[illegible] = cos 0 = 1

[illegible]

These values substituted in MacLaurin's theorem give

$$\cos x = 1 - \frac{x^2}{1 \times 2} + \frac{x^4}{1 \times 2 \times 3 \times 4} - \frac{x^6}{1 \times 2 \times 3 \times 4 \times 5 \times 6}$$

$$+ \frac{x^{2n-2}}{1 \times 2 \times 3 \times \ldots\ldots 2(n-1)}$$

$$\pm \frac{x^{2n}}{1 \times 2 \times 3 \times \ldots\ldots 2(n-1)(2n)}$$

The ratio of the $(n-1)^{th}$ term and n^{th} term is

$$\frac{x^{2n}}{1 \times 2 \times 3 \times \ldots\ldots 2(n-1)(2n-1)(2n)} \div \frac{x^{2(n-1)}}{1 \times 2 \times 3 \times \ldots\ldots 2(n-1)}$$

The series becomes convergent as s[illegible] which condition is fulfilled when [illegible] $\frac{x^2}{2n(2n-1)}$ and $\frac{x^2}{2n(2n-1)} < (2n-1)(2n)$.

Series of Complex Quantities

to be an infinite

$$w_0 = u_0 + j\,v_0$$
$$w_1 = u_1 + j\,v_1$$
$$w_2 = u_2 + j\,v_2$$
$$w_3 = u_3 + j\,v_3$$
$$\cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot$$

this series is convergent only when the sum of the n terms of the u's and also the sum of the n terms of the v's approaches a definite finite limit with increasing n. If this is not the case the series is divergent. First expand the series w in two separate series, namely, that of the real parts and that of the imaginary parts. Provided the series of the real parts u and also the series of the imaginary parts $j\,v$ are convergent, it can be shown that the series w is convergent also. In order to prove this, expand each of the above series again into series of positive and negative parts. If these four series are convergent, the given series w is said to be *absolutely convergent.* To render a series absolutely convergent the series of the absolute values of its terms must be convergent. Let $|u_n| = U_n$ (the sign $|\ \ |$ denoting the absolute value) and $|v_n| = U_n = j\,U_n$, the absolute value of j always being 1. Furthermore, let $|w_n| = W_n$. It is assumed that the series $w_0 + w_1 + w_2 + \ .\ .\ .\ .\ .\ .$ is absolutely convergent, i. e., the series $u_0 + u_1 + u_2 + \ .\ .\ .\ .\ .$ and $v_0 + v_1 + v_2 + \ .\ .\ .\ .\ .\ .$ are absolutely convergent, hence the series of their absolute values must be also. It follows that the series $(U_0 + V_0) + (U_1 + V_1) + (U_2 + V_2) + \ .\ .\ .\ .\ .$ is absolutely convergent. The absolute value of a sum is always less than or equal to the sum of the absolute values of the separate quantities; thus we have

$$W_0 \leqq (U_0 + V_0)$$
$$W_1 \leqq (U_1 + V_1)$$
$$W_2 \leqq (U_2 + V_2)$$
$$\cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot$$

therefore the series $W_0 + W_1 + W_2 + \ .\ .\ .\ .$ is convergent or the series $w_0 + w_1 + w_2 + \ .\ .\ .\ .$ absolutely convergent. All that was said in regard to the convergency of previous series holds true for complex series. So the exponential function

$$\epsilon^{\varkappa} = 1 + \varkappa + \frac{\varkappa^2}{1 \times 2} + \frac{\varkappa^3}{1 \times 2 \times 3} + \ .\ .\ .\ .\ . \qquad (105)$$

was found to be convergent for all values of $\varkappa$ (the discussion

used the function a^{x}, but applies to the function ε^{x} equally well); *all* values will now include *complex* values without further specification.

In the above exponential series substitute jx for x, then

$$\varepsilon^{jx} = 1 + jx - \frac{x^2}{1 \times 2} - \frac{jx^3}{1 \times 2 \times 3} + \frac{x^4}{1 \times 2 \times 3 \times 4} + \frac{jx^5}{1 \times 2 \times 3 \times 4 \times 5} - \frac{x^6}{1 \times 2 \times 3 \times 4 \times 5 \times 6} - \ldots\ldots$$

Collecting the real and imaginary terms we have

$$\varepsilon^{jx} = 1 - \frac{x^2}{1 \times 2} + \frac{x^4}{1 \times 2 \times 3 \times 4} - \frac{x^6}{1 \times 2 \times 3 \times 4 \times 5 \times 6} + \ldots\ldots + j\left(x - \frac{x^3}{1 \times 2 \times 3} + \frac{x^5}{1 \times 2 \times 3 \times 4 \times 5} - \frac{x^7}{1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7} + \ldots\ldots\ldots\ldots\right)$$

or by equations (106) and (107)

$$\varepsilon^{jx} = \cos x + j \sin x \tag{108}$$

By giving j a negative sign we obtain

$$\varepsilon^{-jx} = \cos x - j \sin x \tag{109}$$

hence by the addition of (108) and (109)

$$\cos x = \frac{\varepsilon^{jx} + \varepsilon^{-jx}}{2} \tag{110}$$

and by subtraction

$$\sin x = \frac{\varepsilon^{jx} - e^{-jx}}{2j} \tag{111}$$

Considering that $\tan x = \frac{\sin x}{\cos x}$, we have by substitution

$$\tan x = \frac{\varepsilon^{jx} - e^{-jx}}{\varepsilon^{jx} + \varepsilon^{-jx}} \times \frac{1}{j} \tag{112}$$

Thus we have deduced the circular functions in a purely analytical way.

In these equations x may be made equal to jx; then

$$\cos jx = \frac{\varepsilon^{x} + \varepsilon^{-x}}{2}$$

$$\sin jx = \frac{\varepsilon^{-x} + \varepsilon^{x}}{2j} = \frac{\varepsilon^{x} - \varepsilon^{-x}}{2} \times j$$

$$\tan jx = \frac{\varepsilon^{x} - \varepsilon^{-x}}{\varepsilon^{x} + \varepsilon^{-x}} \times j$$

The expressions

$$\frac{\varepsilon^{\varkappa} + \varepsilon^{-\varkappa}}{2}, \quad \frac{\varepsilon^{\varkappa} - \varepsilon^{-\varkappa}}{2}, \quad \frac{\varepsilon^{\varkappa} - \varepsilon^{-\varkappa}}{\varepsilon^{\varkappa} + \varepsilon^{-\varkappa}}$$

are called the hyperbolic cosine, sine and tangent of $\varkappa$, the notation being cosh $\varkappa$, sinh $\varkappa$ and tanh $\varkappa$. Thus we can note analytically the hyperbolic functions as follows:

$$\cosh \varkappa = \cos j\varkappa = \frac{\varepsilon^{\varkappa} + \varepsilon^{-\varkappa}}{2} \tag{113}$$

$$\sinh \varkappa = -j \sin j\varkappa = \frac{\varepsilon^{\varkappa} - \varepsilon^{-\varkappa}}{2} \tag{114}$$

$$\tanh \varkappa = -j \tan j\varkappa = \frac{\varepsilon^{\varkappa} - \varepsilon^{-\varkappa}}{\varepsilon^{\varkappa} + \varepsilon^{-\varkappa}} \tag{115}$$

By aid of these equations the following hyperbolic relations are readily obtained:

$$\cosh 0 = 1; \quad \sinh 0 = 1; \quad \cosh \infty = \sinh \infty = \infty;$$

$$\cosh^2\varkappa - \sinh^2\varkappa = 1$$

$$\sinh(\varkappa \pm y) = \sinh \varkappa \times \cosh y \pm \cosh \varkappa \sinh y$$

$$\cosh(\varkappa \pm y) = \cosh \varkappa \times \cosh y \pm \sinh \varkappa \sinh y$$

$$\tanh(\varkappa \pm y) = \frac{\tanh \varkappa \pm \tanh y}{1 \pm \tanh \varkappa \times \tanh y}$$

$$\sinh \varkappa + \sinh y = 2 \sinh \frac{\varkappa + y}{2} \times \cosh \frac{\varkappa - y}{2}$$

$$\sinh \varkappa - \sinh y = 2 \cosh \frac{\varkappa + y}{2} \times \sinh \frac{\varkappa - y}{2}$$

$$\cosh \varkappa + \cosh y = 2 \cosh \frac{\varkappa + y}{2} \times \cosh \frac{\varkappa - y}{2}$$

$$\cosh \varkappa - \cosh y = 2 \sinh \frac{\varkappa + y}{2} \times \sinh \frac{\varkappa - y}{2}$$

$$\sinh 2\varkappa = 2 \sinh \varkappa \times \cosh \varkappa$$

$$\cosh 2\varkappa = \cosh^2 \varkappa + \sinh^2 \varkappa = 2 \cosh^2 \varkappa - 1 = 1 + 2 \sinh^2 \varkappa$$

$$\sinh 3\varkappa = 3 \sinh \varkappa + 4 \sinh^3 \varkappa$$

$$\cosh 3\varkappa = 4 \cosh^3 \varkappa - 3 \cosh \varkappa$$

$$\tanh 2\varkappa = \frac{2 \tanh \varkappa}{1 + \tanh^2 \varkappa}$$

$$\tanh 3\varkappa = \frac{3 \tanh \varkappa + \tanh^3 \varkappa}{1 + 3 \tanh^2 \varkappa}$$

$$\sinh \frac{\varkappa}{2} = \sqrt{\frac{\cosh \varkappa - 1}{2}}$$

$$\cosh \frac{\varkappa}{2} = \sqrt{\frac{\cosh \varkappa + 1}{2}}$$

$$\tanh \frac{\varkappa}{2} = \sqrt{\frac{\cosh \varkappa - 1}{\cosh \varkappa + 1}} = \sqrt{\frac{(\cosh \varkappa - 1)(\cosh \varkappa + 1)}{(\cosh \varkappa + 1)^2}}$$

$$= \sqrt{\frac{\cosh^2 \varkappa - 1}{(\cosh \varkappa + 1)^2}} = \sqrt{\frac{\sinh^2 \varkappa}{(\cosh \varkappa + 1)^2}} = \frac{\sinh \varkappa}{\cosh \varkappa + 1}$$

$$\cosh \varkappa = \frac{1 + \tanh^2 \frac{\varkappa}{2}}{1 - \tanh^2 \frac{\varkappa}{2}}; \qquad \sinh \varkappa = \frac{2 \tanh \frac{\varkappa}{2}}{1 - \tanh^2 \frac{\varkappa}{2}}$$

In recent years the old geometrical definitions of circular and hyperbolic functions have been superseded by more modern ones; previously they were defined as lengths having reference to arcs of a curve; now they are defined as ratios. In order to give an idea of these definitions, Figs. 12 and 14 are repeated here with their alterations to suit the modern definitions.

According to Dr. Günther the circular functions are defined as follows: In Fig. 12 let $A\,P\,B$ be a circle of unit radius, and let θ denote double the area of the sector $A\,O\,P$; draw $P\,E$ perpendicular to $O\,A$ and $P\,F$ perpendicular to $O\,B$; draw $A\,G$, a tangent to the circle from A terminating in $O\,P$ produced, and $B\,H$, a tangent to the circle at B also terminating in $O\,P$ produced; draw a tangent to the circle at P cutting the axis of $O\,A$ in I and that of $O\,B$ in K. Then the line $P\,E$ or $O\,F$ represents $\sin\theta$; the line $O\,E$ or $F\,P$ $\cos\theta$; $A\,G$ represents $\tan\theta$ and $B\,H$ $\cot\theta$; while $O\,I$ represents $\sec\theta$ and $O\,K$ $\operatorname{cosec}\theta$. θ here is double the area of the sector $O\,A\,P$; if we denote the area of the sector simply by A, we have $\theta = 2\,A$. But the area of a sector of which the bounding arc subtends an angle whose circular measure is θ at the center of the circle, is $\frac{1}{2} r^2 \theta$, whence $A = \frac{1}{2} r^2 \theta$ and $\theta = \frac{2\,A}{r^2}$; as the circle was assumed to have unit radius, and thus $r^2 = 1$, $\theta = 2\,A$ is sufficient, but $\theta = \frac{2\,A}{r^2}$ shows best the *ratio* of twice the area of the sector to the square on the radius.

Fig. 14 represents the equilateral hyperbola of unit semi-diameter r; select a point, P, on the curve and connect P with O; let u denote double the area of the sector $A\,O\,P$; then $F\,P$, the normal from P on to $O\,A$, will represent $\sinh u$; $O\,F$ the

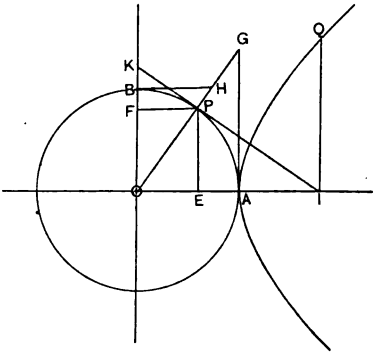

FIG. 12.

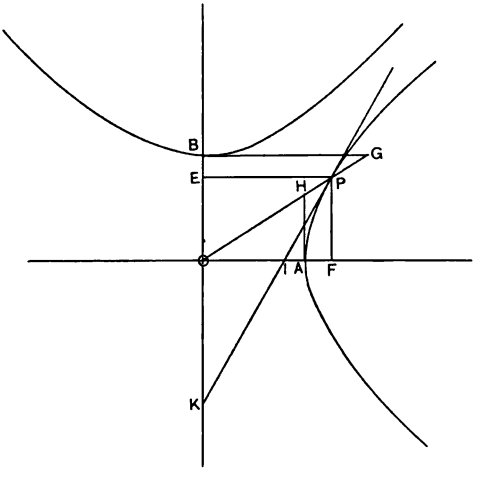

FIG. 14.

cosh u; AH, the normal on OA at A, the tanh u; BG, the normal on OB at B, the coth u; OI (the point I being at the intersection of OA with the tangent to the curve at P) the sech u, and OK (the point K being at the intersection of OB with the tangent to the curve at P) cosech u.

The periodicity of hyperbolic functions can be seen from the following table:

u	sinh u	u	cosh u	u	tanh u	u	coth u
0	0	0	1	0	0	0	∞
$\frac{j\pi}{2}$	j	$\frac{j\pi}{2}$	0	$\frac{j\pi}{2}$	$j\infty$	$\frac{j\pi}{2}$	0
$j\pi$	0	$j\pi$	-1	$j\pi$	0	$j\pi$	∞
$\frac{3j\pi}{2}$	$-j$	$\frac{3j\pi}{2}$	0	$\frac{3j\pi}{2}$	$j\infty$	$\frac{3j\pi}{2}$	0
$2j\pi$	0	$2j\pi$	1	$2j\pi$	0	0	∞

The relation between hyperbolic and circular functions will enable us to compute a table of hyperbolic functions. Hobson, in his treatise on plane trigonometry, states this relation as follows: If we describe a circle of radius $OA = a$ (see Fig. 12), and let P be any point on the circle, PE its ordinate, then, denoting the angle POA by θ, we have area $OAP = \frac{1}{2}a^2\theta$. Let PI be tangent at P; we have then

$$OE = a\cos\theta;\ PE = a\sin\theta;\ PI = a\tan\theta.$$

From I draw IQ perpendicular to OA and equal to PI; then $OI^2 - IQ^2 = a^2$ (for in the rectangular triangle OPI, we have $OI^2 = OP^2 + PI^2$ and PI being $= IQ$, we have also $OI^2 = OP^2 + IQ^2$ or $OI^2 - IQ^2 = OP^2 = a^2$); therefore the locus of Q is a rectangular hyperbola of semi-axis a. (The equation of an equilateral hyperbola is $\frac{x^2}{a^2} - \frac{y^2}{a^2} = 1$, or $x^2 - y^2 = a^2$, x being our OI, y our IQ.) Now denote the area of the sector OAQ by $\frac{1}{2}a^2u$, then $OI = a\cosh u$, $QI = a\sinh u$. Thus we see that just as the ordinate and abscissa of a point P on the circle are denoted by $a\sin\theta$, $a\cos\theta$, respectively, where $\frac{1}{2}a^2\theta$ is the area of the circular sector OAP, so the ordinate and abscissa of the point Q on the rectangular hyperbola are denoted by $a\sinh u$, $a\cosh u$, respectively, where $\frac{1}{2}a^2u$ is the area of the sector OAQ. Thus the hyperbolic sine and cosine have a property in reference to the rectangular hyperbola exactly analogous

to that of the sine and cosine with reference to the circle. Mr. Hayward called the equilateral hyperbola "ex-circle" on account of the analogy between the hyperbolic and circular functions.

Considering the point Q on the rectangular hyperbola, corresponding to the point P on the circle, we have from Fig. 12

$$a \tan \theta = PI = QI = a \sinh u$$
$$\text{and } a \sec \theta = OI = a \cosh u;$$

therefore the arguments θ, u for corresponding points satisfy the relations

$$\tan \theta = a \sinh u$$
$$\text{and } \sec \theta = a \cosh u.$$

Since $\tanh \frac{1}{2} u = \dfrac{\sinh u}{1 + \cosh u}$ we have

$$\tanh \tfrac{1}{2} u = \frac{\tan \theta}{1 + \sec \theta} = \frac{\sin \theta}{1 + \cos \theta} = \tan \tfrac{1}{2} \theta$$

or θ and u satisfy the relation $\tanh \frac{1}{2} u = \tan \frac{1}{2} \theta$. The quantity θ is called the *Gudermannian* of u and abbreviated to $gd\, u$, so that $\theta = gd\, u$.

If we substitute u for $j\varkappa$ and introduce the hyperbolic notation, equation (108) becomes

$$\varepsilon^u = \cosh u + \sinh u = \sec \theta + \tan \theta$$

and therefore $\qquad u = \log_\varepsilon (\sec \theta + \tan \theta)$

$\sec \theta + \tan \theta$ can be transformed as follows:

$$\sec \theta + \tan \theta = \frac{1}{\cos \theta} + \tan \theta = \frac{2}{2 \cos \theta} + \tan \theta$$

$$= \frac{1 + \cos \theta + 1 - \cos \theta}{1 + \cos \theta - (1 - \cos \theta)} + \tan \theta$$

$$= \frac{1 + \dfrac{1 - \cos \theta}{1 + \cos \theta}}{1 - \dfrac{1 - \cos \theta}{1 + \cos \theta}} + \tan \theta$$

$$= \frac{1 + \tan^2 \dfrac{\theta}{2}}{1 - \tan^2 \dfrac{\theta}{2}} + \tan \theta$$

$$= \frac{1 + \tan^2 \dfrac{\theta}{2} + 2 \tan \dfrac{\theta}{2}}{1 - \tan^2 \dfrac{\theta}{2}}$$

[illegible] the nor-
[illegible] the inter-
[illegible] the sect[illegible]
[illegible] with the
[illegible]
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[illegible]

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible] will [illegible] hyperbolic functions. Hobson, [illegible] trigonometry, states this relation as follows: [illegible] circle, radius $a = 1$ (see Fig. 12), [illegible] ordinate, then, denoting the area [illegible] we have area $OAP = \frac{1}{2}a^2\theta$. [illegible] we have then

$$[illegible] = a \sin\theta, \quad [illegible] = a \tan\theta.$$

[illegible] and equal to PI; then [illegible] the rectangular triangle OPI, we have [illegible] being $= [illegible]$ we have also [illegible] $OP = IP = OP = a^2$; therefore [illegible] rectangular hyperbola of semi-axis a [illegible]

[illegible] an equilateral hyperbola is $\frac{x^2}{a^2} - \frac{y^2}{a^2} = [illegible]$

[illegible] being on [illegible] on IQ. Now denote [illegible] QI by a [illegible] then $OI = a \cosh u$, PI [illegible] see that just as the ordinate and a[illegible] circle are denoted by $a \sin\theta$, $a \cos\theta$ [illegible] the area of the circular sector OA [illegible] of the point Q on the rectang[illegible] $a \sinh u$, $a \cosh u$, respectivel[illegible] sector OAQ. Thus the hy[illegible] erty in reference to the rec[illegible]

to that of the sine and cosine with reference to the circle. Mr. Hayward called the equilateral hyperbola "ex-circle" on account of the analogy between the hyperbolic and circular functions.

Considering the point Q on the rectangular hyperbola, corresponding to the point P on the circle, we have from Fig. 12

$$a \tan \theta = PI = QI = a \sinh u$$

$$\text{and } a \sec \theta = OI = a \cosh u;$$

therefore the arguments θ, u for corresponding points satisfy the relations

$$\tan \theta = a \sinh u$$

$$\text{and } \sec \theta = a \cosh u.$$

Since $\tanh \frac{1}{2} u = \dfrac{\sinh u}{1 + \cosh u}$ we have

$$\tanh \tfrac{1}{2} u = \frac{\tan \theta}{1 + \sec \theta} = \frac{\sin \theta}{1 + \cos \theta} = \tan \tfrac{1}{2} \theta$$

or θ and u satisfy the relation $\tanh \frac{1}{2} u = \tan \frac{1}{2} \theta$. The quantity θ is called the *Gudermannian* of u and abbreviated to $gd\, u$, so that $\theta = gd\, u$.

If we substitute u for $j\varkappa$ and introduce the hyperbolic notation, equation (108) becomes

$$\varepsilon^{u} \quad \text{h } u + \text{s} \quad u = \sec \theta + \tan \theta$$

and therefore

$$= \text{lo} \quad + \tan \theta)$$

$\sec \theta + \tan$ ans follows:

$$\theta = \quad \tan \theta = \frac{2}{2 \cos \theta} + \tan \theta$$

$$\frac{1}{} \quad \frac{- \cos \theta}{1 - \cos \theta} + \tan \theta$$

$$\theta$$

$$\theta$$

$$\cos \theta$$

$$\cos$$

$$\tan^2$$

$$2 \tan \frac{\theta}{2}$$

$$\tan^2 \frac{\theta}{2}$$

$$= \frac{\left(1 + \tan\frac{\theta}{2}\right)^2}{1 - \tan^2\frac{\theta}{2}}$$

$$= \frac{1 + \tan\frac{\theta}{2}}{1 - \tan\frac{\theta}{2}}$$

$$= \frac{\tan\frac{\pi}{4} + \tan\frac{\theta}{2}}{1 - \tan\frac{\pi}{4}\tan\frac{\theta}{2}}$$

$$= \tan\left(\frac{\pi}{4} + \frac{\theta}{2}\right)$$

hence

$$u = \log_\varepsilon (\sec\theta + \tan\theta) = \log_\varepsilon \tan\left(\frac{\pi}{4} + \frac{\theta}{2}\right)$$

and we obtain, finally,

$$u = gd^{-1}\theta = \log_\varepsilon \tan\left(\frac{\pi}{4} + \frac{\theta}{2}\right)$$

Thus, using a table of natural tangents and secants of angles, a table of hyperbolic functions can be computed.

Table of Hyperbolic Functions.—In the following table the values of $\sinh u$ and $\cosh u$ are given for the values of u from 0 to 10. Also the log's of $\sinh u$ and $\cosh u$ directly for the values of u from 1 to 10, while the log's of $\sinh u$ and $\cosh u$ for the values of u from 0 to 1 may easily be deduced from the values given for $gd\,u$ by the aid of a table of log's of trigonometric numbers, remembering that

$$\log\sinh u = \log\tan(gd\,u)$$

$$\text{and} \quad \log\cosh u = \log\sec(gd\,u)$$

As a table of log's of trigonometric numbers does not usually contain the log sec, find the log $\cos^{-1}$ which is the same. The values of ε^u and ε^{-u} for values of u from 0 to 1 are given, because they are of frequent occurrence in alternating current problems. Professor Byerly's and Professor Peirce's tables have been used as far as they go; the balance has been computed. The last decimal place is approximate only.

TABLE OF HYPERBOLIC FUNCTIONS.

u	ε^u	ε^{-u}	sinh u	cosh u	$gd\, u$
0.00	1.0000	1.0000	0.0000	1.0000	0°.0000
.01	1.0100	0.9900	0.0100	1.00005	0° 5729
.02	1.0202	0.9802	0.0200	1.00020	1°.1458
.03	1.0305	0.9704	0.0300	1.00045	1°.7186
.04	1.0408	0.9608	0.0400	1.00080	2°.2912
.05	1.0513	0.9512	0.0500	1.00125	2°.8636
.06	1.0618	0.9418	0.0600	1.00180	3°.4357
.07	1.0725	0.9324	0.0701	1.00245	4°.0074
.08	1.0833	0.9231	0.0801	1.00320	4°.5788
.09	1.0942	0.9139	0.0901	1.00405	5°.1497
.10	1.1052	0.9048	0.1002	1.00500	5°.720
.11	1 1163	0.8958	0.1102	1.0061	6°.290
.12	1.1275	0.8869	0.1203	1.0072	6°.859
.13	1.1388	0.8781	0.1304	1.0085	7°.428
.14	1.1503	0.8694	0.1405	1.0098	7°.995
.15	1.1618	0.8607	0.1506	1.0113	8°.562
.16	1.1735	0.8521	0.1607	1.0128	9°.128
.17	1.1853	0.8437	0.1708	1.0145	9°.694
.18	1.1972	0.8353	0.1810	1.0162	10°.258
.19	1.2092	0.8270	0.1911	1.0181	10°.821
.20	1.2214	0.8187	0.2013	1.0201	11°.384
.21	1.2337	0.8106	0.2115	1.0221	11°.945
.22	1.2461	0.8025	0.2218	1.0243	12°.505
.23	1.2586	0.7945	0.2320	1.0266	13°.063
.24	1.2712	0.7866	0.2423	1.0289	13°.621
.25	1.2840	0.7788	0.2526	1.0314	14°.177
.26	1.2969	0.7711	0.2629	1.0340	14°.732
.27	1.3100	0.7634	0.2733	1.0367	15°.285
.28	1.3231	0.7558	0.2837	1.0395	15°.837
.29	1.3364	0.7483	0.2941	1.0423	16°.388
.30	1.3499	0.7408	0.3045	1.0453	16°.937
.31	1.3634	0.7334	0.3150	1.0484	17°.484
.32	1.3771	0.7261	0.3255	1.0516	18°.030
.33	1.3910	0.7189	0.3360	1.0549	18°.573
.34	1.4049	0.7118	0.3466	1.0584	19°.116
.35	1.4191	0.7047	0.3572	1.0619	19°.656
.36	1.4333	0.6977	0.3678	1.0655	20°.195
.37	1.4477	0.6907	0.3785	1.0692	20°.732
.38	1.4623	0.6839	0.3892	1.0731	21°.267
.39	1 4770	0.6771	0.4000	1.0770	21°.800
.40	1.4918	0.6703	0.4108	1.0811	22°.331
.41	1.5068	0.6636	0.4216	1.0852	22°.859
.42	1.5220	0.6570	0.4325	1.0895	23°.386
.43	1.5373	0.6505	0.4434	1.0939	23°.911
.44	1.5527	0.6440	0.4543	1.0984	24°.434
.45	1.5683	0.6376	0.4653	1.1030	24°.955
.46	1.5841	0.6313	0.4764	1.1077	25°.473
.47	1.6000	0.6250	0.4875	1.1125	25°.989
.48	1.6161	0.6188	0.4986	1.1174	26°.503
.49	1.6323	0.6126	0.5098	1.1225	27°.015
.50	1.6487	0.6065	0.5211	1.1276	27°.524

TABLE OF HYPERBOLIC FUNCTIONS.

u	ε^{u}	ε^{-u}	sinh u	cosh u	$gd\ u$
0.51	1.6653	0.6005	0.5324	1.1329	28°.031
.52	1.6820	0.5945	0.5438	1.1383	28°.535
.53	1.6989	0.5886	0.5552	1.1438	29°.037
.54	1.7160	0.5827	0.5666	1.1494	29°.537
.55	1.7333	0.5770	0.5782	1.1551	30°.034
.56	1.7507	0.5712	0.5897	1.1609	30°.529
.57	1.7683	0.5655	0.6014	1.1669	31°.021
.58	1.7860	0.5599	0.6131	1.1730	31° 511
.59	1.8040	0.5543	0.6248	1.1792	31°.998
.60	1.8221	0.5488	0.6367	1.1855	32°.483
.61	1.8404	0.5433	0.6485	1.1919	32°.965
.62	1.8589	0.5379	0.6605	1.1984	33°.444
.63	1.8776	0.5326	0.6725	1.2051	33°.921
.64	1.8965	0.5273	0.6846	1.2119	34°.395
.65	1.9155	0.5220	0.6967	1.2188	34°.867
.66	1.9348	0.5169	0.7090	1.2258	35°.336
.67	1.9542	0.5117	0.7213	1.2330	35° 802
.68	1.9739	0.5066	0.7336	1.2402	36° 265
.69	1.9937	0.5016	0.7461	1.2476	36°.726
.70	2.0138	0.4966	0.7586	1.2552	37°.183
.71	2.0340	0.4916	0.7712	1.2628	37°.638
.72	2.0544	0.4867	0.7838	1.2706	38°.091
.73	2.0751	0.4819	0.7966	1.2785	38°.540
.74	2.0959	0.4771	0.8094	1.2865	38°.987
.75	2.1170	0.4724	0.8223	1.2947	39°.431
.76	2.1383	0.4677	0 8353	1.3030	39°.872
.77	2.1598	0.4630	0.8484	1.3114	40°.310
.78	2.1815	0.4584	0.8615	1.3199	40°.746
.79	2.2034	0.4538	0.8748	1.3286	41°.179
.80	2.2255	0 4493	0.8881	1.3374	41°.608
.81	2 2479	0.4449	0.9015	1.3464	42°.035
.82	2.2705	0.4404	0.9150	1.3555	42°.460
.83	2.2933	0.4360	0.9286	1.3647	42° 881
.84	2.3164	0.4317	0.9423	1.3740	43°.299
.85	2.3396	0.4274	0.9561	1.3835	43°.715
.86	2.3632	0.4232	0.9700	1.3932	44°.128
.87	2.3869	0.4190	0.9840	1.4029	44°.537
.88	2.4109	0.4148	0.9981	1.4128	44°.944
.89	2.4351	0.4107	1.0122	1.4229	45°.348
.90	2.4596	0.4066	1.0265	1.4331	45°.750
.91	2.4843	0.4025	1.0409	1.4434	46°.148
.92	2.5093	0.3985	1.0554	1.4539	46°.544
.93	2.5345	0.3946	1.0700	1.4645	46°.936
.94	2.5600	0.3906	1.0847	1.4753	47°.326
.95	2.5857	0.3867	1.0995	1.4862	47°.713
.96	2.6117	0.3829	1.1144	1.4973	48°.097
.97	2.6379	0.3791	1.1294	1.5085	48°.478
.98	2.6645	0.3751	1.1446	1.5199	48°.857
.99	2.6912	0.3716	1.1598	1.5314	49°.232
1.00	2.7183	0.3679	1.1752	1.5431	49°.605

TABLE OF HYPERBOLIC FUNCTIONS.

u	sinh u	cosh u	log sinh u	log cosh u
1.00	1.1752	1.5431	0.0701	0.1884
1.01	1.1907	1.5550	0.0758	0.1917
1.02	1.2065	1.5671	0.0815	0.1950
1.03	1.2221	1.5791	0.0871	0.1984
1.04	1.2380	1.5915	0.0927	0.2018
1.05	1.2538	1.6039	0.0982	0.2051
1.06	1.2700	1.6166	0 1038	0.2086
1.07	1.2862	1.6293	0.1093	0.2120
1.08	1.3026	1.6422	0.1148	0.2154
1.09	1.3192	1.6554	0.1203	0.2189
1.10	1.3357	1.6685	0.1257	0.2223
1.11	1.3524	1.6819	0.1311	0.2258
1.12	1.3694	1.6956	0.1365	0.2293
1.13	1.3865	1.7093	0.1419	0.2328
1.14	1 4035	1.7235	0.1472	0.2364
1.15	1.4207	1.7375	0.1525	0.2399
1.16	1.4382	1.7519	0.1578	0.2435
1.17	1.4558	1.7660	0.1631	0.2470
1.18	1.4737	1.7806	0.1684	0.2506
1.19	1.4915	1.7955	0.1736	0.2542
1.20	1.5094	1.8106	0.1788	0 2578
1.21	1.5276	1.8260	0.1840	0.2615
1.22	1.5460	1.8412	0.1892	0.2651
1.23	1.5646	1.8570	0.1944	0.2688
1.24	1.5831	1.8725	0.1995	0.2724
1.25	1.6018	1.8885	0.2046	0.2761
1.26	1.6211	1.9046	0.2098	0.2798
1.27	1.6399	1.9209	0.2148	0.2835
1.28	1.6593	1.9374	0.2199	0.2872
1.29	1.6789	1.9539	0.2250	0.2909
1.30	1.6983	1.9709	0.2300	0.2947
1.31	1.7184	1.9880	0.2351	0.2984
1.32	1.7383	2.0054	0.2401	0.3022
1.33	1.7584	2.0235	0.2451	0.3059
1 34	1.7787	2.0404	0.2501	0.3097
1.35	1.7993	2.0583	0.2551	0.3135
1.36	1.8198	2.0763	0.2600	0.3173
1.37	1.8408	2.0946	0.2650	0.3211
1.38	1.8607	2.1130	0.2699	0.3249
1.39	1.8828	2.1321	0.2748	0.3288
1.40	1.9042	2.1509	0.2797	0.3326
1.41	1.9258	2.1703	0.2846	0.3365
1.42	1.9477	2.1893	0.2895	0.3403
1.43	1.9697	2.2091	0.2944	0.3442
1.44	1.9921	2.2290	0.2993	0.3481
1.45	2.0142	2.2491	0.3041	0.3520
1.46	2.0371	2.2694	0.3090	0.3559
1 47	2.0597	2.2899	0.3138	0.3598
1.48	2.0856	2.3105	0.3186	0.3637
1.49	2.1068	2.3314	0.3234	0.3676
1.50	2.1292	2.3524	0.3282	0.3715

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE OF HYPERBOLIC FUNCTIONS.

u	sinh u	cosh u	log sinh u	log cosh u
2.01	3.6644	3.7984	0.5640	0.5796
2.02	3.7025	3.8354	0.5685	0.5838
2.03	3.7412	3.8726	0.5730	0.5880
2.04	3.7801	3.9103	0.5775	0.5922
2.05	3.8195	3.9483	0.5820	0.5964
2.06	3.8593	3.9866	0.5865	0.6006
2.07	3.8995	4.0254	0.5910	0.6048
2.08	3.9401	4.0645	0.5955	0.6090
2.09	3.9811	4.1040	0.6000	0.6132
2.10	4.0217	4.1443	0.6044	0.6175
2.11	4.0635	4.1852	0.6089	0.6217
2.12	4.1059	4.2258	0.6134	0.6259
2.13	4.1477	4.2668	0.6178	0.6301
2.14	4.1909	4.3083	0.6223	0.6343
2.15	4.2345	4.3512	0.6268	0.6386
2.16	4.2776	4.3934	0.6312	0.6428
2.17	4.3222	4.4361	0.6357	0.6470
2.18	4.3662	4.4792	0.6401	0.6512
2.19	4.4117	4.5238	0.6446	0.6555
2.20	4.4576	4.5679	0.6491	0.6597
2.21	4.5030	4.6132	0.6535	0.6640
2.22	4.5499	4.6581	0.6580	0.6682
2.23	4.5963	4.7033	0.6624	0.6724
2.24	4.6431	4.7501	0.6668	0.6767
2.25	4.6914	4.7963	0.6713	0.6809
2.26	4.7392	4.8440	0.6757	0.6852
2.27	4.7886	4.8911	0.6802	0.6894
2.28	4.8373	4.9397	0.6846	0.6937
2.29	4.8866	4.9877	0.6890	0.6979
2.30	4.9375	5.0372	0.6935	0.7022
2.31	4.9832	5.0863	0.6975	0.7064
2.32	5.0385	5.1369	0.7023	0.7107
2.33	5.0898	5.1880	0.7067	0.7150
2.34	5.1429	5.2385	0.7112	0.7192
2.35	5.1952	5.2906	0.7156	0.7235
2.36	5.2481	5.3433	0.7200	0.7278
2.37	5.3016	5.3952	0.7244	0.7320
2.38	5.3568	5.4488	0.7289	0.7363
2.39	5.4113	5.5031	0.7333	0.7406
2.40	5.4664	5.5569	0.7377	0.7448
2.41	5.5221	5.6108	0.7421	0.7491
2.42	5.5783	5.6677	0.7465	0.7534
2.43	5.6351	5.7241	0.7509	0.7577
2.44	5.6925	5.7797	0.7553	0.7619
2.45	5.7505	5.8372	0.7597	0.7662
2.46	5.8104	5.8953	0.7642	0.7705
2.47	5.8695	5.9539	0.7686	0.7748
2.48	5.9293	6.0132	0.7730	0.7791
2.49	5.9897	6.0716	0.7774	0.7833
2.50	6.0507	6.1323	0.7818	0.7876

[illegible] HYPERBOLIC FUNCTIONS.

[illegible]	sh x	∠ sinh x	∠ cosh x
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

TABLE OF HYPERBOLIC FUNCTIONS.

u	sinh u	cosh u	log sinh u	log cosh u
3.1	11.077	11.123	1.0444	1.0462
3.2	12.247	12.286	1.0880	1.0894
3.3	13.540	13.574	1.1316	1.1327
3.4	14.966	15.001	1.1751	1.1761
3.5	16.543	16.573	1.2186	1.2194
3.6	18.286	18.315	1.2621	1.2628
3.7	20.212	20.235	1.3056	1.3061
3.8	22.342	22.362	1.3491	1.3495
3.9	24.689	24.712	1.3925	1.3929
4.0	27.303	27.3082	1.4362	1.4363
4.1	30.165	30.179	1.4795	1.4797
4.2	33.335	33.351	1.5229	1.5231
4.3	36.848	36.856	1.5664	1.5665
4.4	40.720	40.730	1.6098	1.6099
4.5	44.999	45.010	1.6532	1.6533
4.6	49.740	49.751	1.6967	1.6968
4.7	54.967	54.980	1.7401	1.7402
4.8	60.758	60.758	1.7836	1.7836
4.9	67.143	67.143	1.8270	1.8270
5	74.200	74.217	1.8704	1.8705
6	201.70	201.70	2.3047	2.3047
7	548.28	548.28	2.7390	2.7390
8	1,490.4	1,490.4	3.1733	3.1733
9	4,051.4	4,051.4	3.6076	3.6076
10	11,013	11,013	4.0419	4.0419

[illegible] and the tops [illegible] platinum wire about [illegible] an ordinary sewing needle is threaded with [illegible] platinum wire and the mantle is gathered where it [illegible] One half of the circumference of the mantle is [illegible] gathered a loop is then made in the platinum wire, after [illegible] the other half of the circumference of the mantle is gathered. The two ends of the platinum wire then projecting are [illegible] the loop is cut, and the mantle (for it is now [illegible] a web) is ready to be modeled.

[illegible] the mantle is placed over a wooden block which [illegible] the finished product. The mantle is stretched [illegible] out to make the stitches even and

[illegible] Philadelphia.

take out all wrinkles. After it is perfectly smooth, the wire support, which may be of iron and nickel, is placed centrally over the top of the mantle, and the platinum wire is twisted around the ring at the top of the support.

So far we have been dealing with the saturated webs and mantles of cotton, but now we are ready to burn out this cotton and leave a reproduction of it in oxides. To burn out the cotton from the saturated webs, the mantle supports are placed in a block in front of the operator, allowing the mantles to hang naturally. Each mantle is then touched at the top with a Bunsen flame and the cotton is slowly consumed. It is only necessary to touch the mantle once with the flame, as the cotton will burn by itself.

Immediately after burning out the cotton, the oxides are in a very soft condition, and it is necessary to harden them in order to give them the shape that will produce the best results in lighting. This shape should conform as nearly as possible to that of the Bunsen flame, for the flame should just fill the mantle without enveloping it with a thick flame on the outside — that is, if there is too much flame on the outside the radiating power of the mantle becomes very much less, and the candle-power is low.

After being exposed to the flame for some time the mantles become quite hard, and if they are given the proper shape soon after the cotton is burned out, they will retain this shape; so after the cotton is burned out, the operator places the mantle over a soft Bunsen flame, and with a piece of talc gives it the proper shape. The mantles are then mounted on bars where gas is burned in them under pressure, and they are left exposed to a very high temperature until they reach the proper degree of hardness.

At this stage, while the mantles are comparatively hard, they are brittle, and any rough handling will cause them to break, so, in order to render them capable of transportation, they are dipped into a coating which fills up the stitches and fibers and renders the entire mantle one flexible body. The mantles are now trimmed off at the bottom to the proper length, and are packed in tubes for shipment or mounted on the gallery (as the brass part of the lamp is called) and sent to the consumer.

When the complete light reaches the consumer (if it is a complete light), the Bunsen tube is screwed on to the fixture and the

air supply is adjusted by the air shutter in such a manner that the flame is just ready to "flash back." A match is then applied to the top of the mantle, care being taken that the match stick does not hit the mantle, and the flexible coating is burned off. This being a very inflammable substance, but a few seconds will be required. After this the mantle is ready for use, the gallery may be put upon the Bunsen, the gas turned on and lighted at the top.

In sending out mantles to be put upon lamps that are already in position, it is only necessary to see that the mantle is placed centrally over the gauze cap of the gallery and adjusted to the proper height. After this has been done it is only necessary to proceed as in installing a complete light as before.

The process of manufacture, though it sounds like a simple one, is extremely difficult, and it is absolutely necessary that the labor must be skilled and subdivided in order to get the best results. A rigid system of inspection is also essential. . . .

During the discussion that followed Mr. Barrows explained that the variation sometimes noticed in two burners is probably due to dust in the adjustments. Some of the air shutters are very loose and a jar will cause the air shutters to close or open. Then again very often tar or some other impurity may be carried in the gas and pass more into one burner than into another. By blowing out the fixtures and adjusting the burners the light will probably be the same. By varying the fluid, the preparation of which is not a secret and may be made from any of the rarer earths, we can get a different light, from a pure white light down to a deep orange. People complained of the pure white light, often thinking it was green, and since then it has been changed very slightly. There is also some difference in the color of the glass chimneys. . . . The quality of the illumination is often due to the heating quality of the gas. You very often notice black spots on the mantles, which show that there is not complete combustion and carbon is condensed on the mantle. By proper adjustment this may all be burned off. We have found that carpet stores are especially hard on mantles, on account of the vibrations. In showing a roll of carpet the salesman drops it on the floor, thus jarring the mantle. We have put in a fixture to counteract vibration, and the lamps have since been burning for some time without a break, where before they would not last for five minutes.

THE TELEPHONE CONVENTION.

It was a happy thought that resulted in the election of Judge Barstow as the presiding officer of the convention, for the honorable judge is a prince among optimists and a firm believer in the gospel of good cheer. Thus, no amount of croaking could entirely dispel that hearty cheerfulness that permeated every session. To be sure, now and then, the discussions were tinged with melancholy, and on the whole the proceedings were of a depressing character, but the judge was as bland as the honey of Hyblea. What matter if Waukesha had "ceased business and sold the plant for a nominal sum, sufficient to cover outstanding indebtedness, leaving the original investment a total loss"; that LaGrange had gladly laid down its burden and pocketed the loss; that Selma's doors had been slammed in the face of an ungrateful public who could now pay the higher rates of the Bell Company, simply because they desired some return on an investment that ought to have been given freely from a sense of pride in a home institution. To be sure, the officials admitted that the prices charged and the service rendered were so unsatisfactory that the service had to be abandoned, but their opinion was naturally biased. Or that St. Joe was wondering how so much money could be forever lost so quickly, though the local press laid the blame on "unsatisfactory service — want of out-of-town connections, inferior appliances to the Bell Company, and a rate too low to enable them to attempt a comprehensive service." Suppose the competing telephone plant at Nevada that cost $2,000 was sold for $150, and that the Pittsburg plant on which over $3,000 was invested was disposed of under the hammer for $600 — Did not the smooth promoter get away with his commission? What if the courts have ordered the notorious Harrison Topeka telephone plant to be sold to satisfy judgements aggregating $30,000. Is there not an abundance of wealth yet remaining in Kansas yearning for just such profitable investments? And who can locate a soft mark quite so quickly as the slick telephone promoter who was the understudy of Dusty Rhoades but a brief space agone? Why should the learned judge care if the Florida Long Distance

Telephone system was disposed of for $150 at Orlanda, by a brutal sheriff clothed with a little brief authority? or that the Ypsilanti automatic telephone exchange had been discontinued? The judge was content to look upon the bright side of life, even if twelve members had been sidetracked by the sheriff, or for some similar reason, since the last meeting; for he well knew that though the hot sun was now roasting the members, yet with the opening of the gates of night would come the stars and the cooling breeze and the refreshing sleep. And in that land of dreams that yet may prove to be the real world there is no worry over doomed financial ventures voluntarily assumed. So, why worry?

And having called the meeting to order, the judge declared the convention of independent telephone companies open and directed the calling of the roll. This being done, the secretary reported a gain of twenty-two new members and a loss of twelve members. As the names of these twelve delinquent members were called only harsh and unpleasant comments were heard on every side, due, apparently, to no other cause than that some among these ill-fated twelve had allowed an uninvited and ill-bred deputy sheriff to enter their respective exchanges and levy on the entire plant, merely to satisfy claims for small amounts of filthy lucre.

But the judge rapped for order, and said the remarks were uncalled for. "We should learn to bear easily the misfortunes of our friends, and, with Euripides, remember that that man is wise among us, and hath understanding of things divine, who hath nobly agreed with necessity."

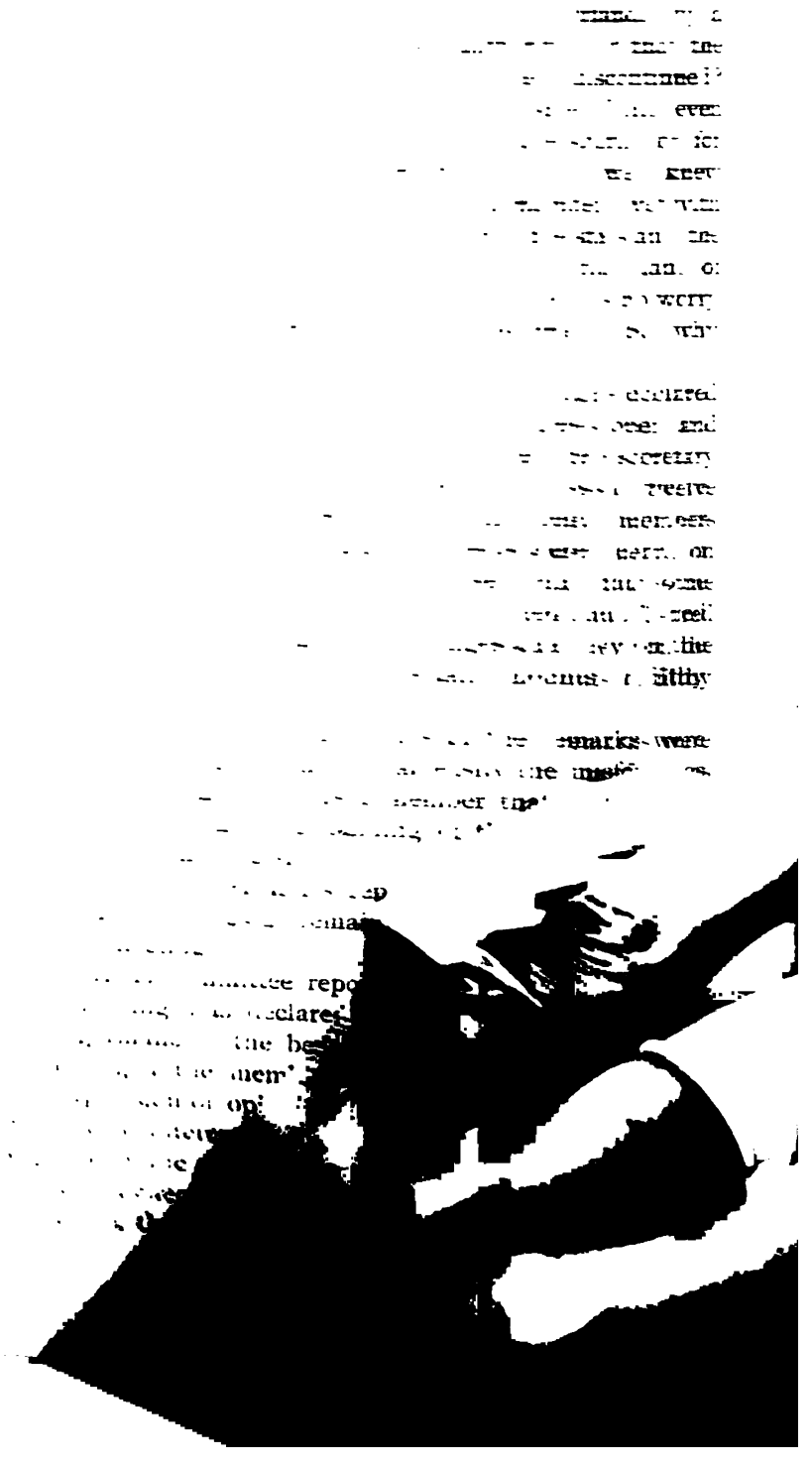
The reading of the treasurer's report showed no indebtedness, and a balance of $203.40 remaining on hand to defray the expenses of this meeting.

After the various committee reports had been read and disposed of, the meeting was declared open for the discussion of special topics germane to the best interests of the association, and the chair urged the members to participate in a full and spontaneous expression of opinion on the rumored consolidation of all the property interests of the principal Bell licensees and their absorption by the parent company, thus doing away with the royalty fee and effecting a marked reduction in the operating expenses, enabling them the better to meet competition.

The chair also desired that the sentiment of the association be placed on record regarding the attitude of the manufacturing telephone companies toward the operating telephone companies.

He did not believe that the manufacturing companies were standing up as manfully as they had agreed to, and there was little doubt in his mind that the independent exchanges would have to fight their own battles, while the manufacturing companies exhausted their energy in petty internal squabbles. Thus he believed that the association was not interested so much in what the telephone manufacturing companies were going to do, as whom ; for experience had shown how honest they could be when certain of being detected. Nor would he advise any member to lean on any telephone manufacturer for legal assistance in defending the suits the Bell Company would certainly institute. For, basing his opinion on personal observation, and the published statements in the electrical press, the chair felt confident that the affairs of these manufacturing companies were in such shape that they could immediately close down or assign, in the event of the United States Supreme Court again deciding in favor of the Bell interests. Thus it is really the part of wisdom to look upon the bond and the guarantee of telephone manufacturers as absolutely valueless, for the court proceedings already taken show that some, if not all, "are pecuniarily irresponsible and unable to respond to a decree for damages in favor of the complainant in this suit."

The question was asked by one of the members whether there was any reliable information on record regarding the financial standing of the Home Telephone Company, claiming several thousand subscribers in many cities, according to the very reliable electrical journals. The secretary replied by reading extracts from a report on the Committee on Telephones for the District of Columbia, on bill S. 2,498, showing a claim on the part of the promoter of having secured 3,400 subscribers in the District of Columbia, at a rate of $40 and $32, taken from "the portion of the business people of the city who have not been so successful in life, and who have no particular use for the more expensive metallic connection." "We expect to serve people who cannot quite afford to use telephones unless this company is chartered." The gist of the testimony showing that "if the franchise were granted today, two years from now would not see two hundred commer-



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cially working Home telephones in the District of Columbia, if any." The Secretary also read extracts from the Cleveland *Plain Dealer* and the Cleveland *Leader*, of May 12, 1895, showing that the Home Company "has no serious intention at present of going ahead with its project." Yet in each city they were successful in disposing of privileges, stock, etc., at good prices.

These comments reminded the president of the story of the practical politician who boasted that he had made $200,000 in the last two years, "but I worked for it." "Of course you did," was the reply, "but whom did you work?"

Mayor Pingree's Detroit Telephone Company, that is to be operated for fifty per cent less than the present Exchange, next came in for a fair share of criticism for masterly inactivity, and in closing this discussion later on, the chair remarked that the good mayor's comments on the absence of proper protection for the rights of the people were worthy of the able politician who said that all knowledge which does not increase a man's virtue makes him the more dangerous. And he recalled a brief conversation between two politicians, accidentally overheard in one of the lower wards in his city: "You look done up, Chimmy. Is it worryin' yuh to make all those reform speeches to the people of your ward?" "It isn't the reform speeches, Tim, it's the work of gettin' the boys to understand how I don't mean 'em, that's worryin' me."

The deduction drawn from the printed statements issued by this Detroit Company is, that with an average telephone rental of $34 a year for 5,000 telephones, 10 per cent dividends can be paid on $600,000 in capital stock, and 6 per cent on $400,000 in bonds. And all purchasers of stock would be given an equal amount of interest bearing bonds. In other words, this "reform" organization would not pattern after the highly improper methods adopted by the grasping corporations so heartily denounced by his honor, "the friend of the people," but would add the water before winning success. In the prospectus issued by the Pingree-Detroit Company, earnings and expenses are itemized, thus enabling a comparison to be made with the present expense account of the Bell Company in Detroit, having 4,300 subscribers.

Female switch board operators, Pingree Company, 60 at $5 a week, or $15,000 annually; Bell Company, 107, averaging $6

per week, or $33,384 annually. The Pingree Company will have 10 linemen and 3 laborers, at an annual outlay of $7,500, while the Bell Company finds it necessary to keep 56 linemen and inspectors continually employed at an expense of $33,600. Batteries have to be renewed every few weeks, this item aggregating $10,000 annually for the Bell Company, yet the Pingree Company makes no provision for this very necessary expenditure. For new material and repairs to Bell circuits nearly $25,000 are expended annually, yet the Pingree prospectus makes no allowance for this, nor for depreciation, though in 1893 the Bell Company replaced a switch board that cost $54,000 with one that cost $124,000, and had previously discarded boards costing over $60,000. Yet the Pingree Company add: "And on every additional 1,000 telephones used, the net profit per annum would be $25,000, the ratio of profit being higher as subscribers increase."

The member from Pittsburg suggested that the Pingree Company should secure the services of the bland promoter who has been weaving his meshes about the gullible citizens of Kansas City, as he possessed the ability of operating an exchange of 3,000 telephones at a total expense covering all items, averaging but $12 per telephone, while the Pingree Company allowed the extravagant sum of $15.30 per instrument. To be sure, the Bell Company claims that it costs them about $60 an instrument to operate their exchange, but who believes the fairy tales of successful dividend-paying corporations? Then this Kansas City weaver offers his telephones at only $32 a year, and his circular clearly demonstrates that if only 3,000 telephones are rented at $32, the annual income will be $96,000, the total annual expense $36,000, leaving the handsome net income of $60,000, or a return of 12 per cent on an investment of $500,000. But for fear that the holders of this stock may become proud in spirit, the weaver limits the number of shares that any one person should hold to ten shares of $100 each.

Comment was also made on the promised competition that has failed to materialize in Chicago, Philadelphia, St. Louis and other large cities, and to the feeling of pride that must permeate the bosoms of Messrs. Clarkson, Egan, Tracy, Aldrich, Porter et al., when they gaze upon all that has been accomplished.

Incidentally, the chair remarked that there was ample legal talent both within and without the association ready for sacrifice

[illegible]

patrons, rather than from any expected profit that would accrue from village conversations. Rarely will the public pay more than 1 cent a mile for short distances of fifty miles or less, and ½ cent for distances exceeding fifty miles, and as an average of only five conversations per hour can be held over any ordinary toll line, the income never justifies the outlay save from the standpoint of favoring the subscribers of the large exchange."

A spirited discussion followed in which nearly every member participated, but it was soon evident that some prearranged plan existed for forcing the association to indorse a movement in favor of toll lines. The minority protested against any action that necessitated further expenditures of moneys. Toll lines were necessarily expensive to build properly, as well as difficult to maintain in good working order in this section so often visited by severe storms, while it was doubtful if the receipts would ever equal the cost of operating the lines; and as not one dollar of legitimate profit had yet been secured from any investment in these small independent exchanges, any motion to increase the investment until a dividend had been declared would meet with determined resistance. Even with their more profitable rates the Bell Companies did not dream of general toll lines for several years after the principal exchanges had been established, and only since August 1 has it been possible to talk direct from Davenport to eastern points over the long-distance trunk lines.

Mr. Cleveland said that he fully appreciated the great value to a local exchange of the right of way for transmission of messages over trunk lines, and he felt that in the near future some concerted action that might bring about interstate connections would be not only desirable, but absolutely essential to preserve the integrity of the capital already invested. But this was not the time nor the place to adopt coercive measures. No one appreciated more fully than he did the great value of the telephone as a time saver to business men, and he had heard of many instances of men traveling by rail to Chicago and then using the long-distance lines to close some important deal in Boston or New York, or some eastern city. But these long-distance trunk lines were owned by a separate company, and built and maintained by capital invested independently of any investment in the local exchange. No doubt an independent long-distance company might be formed — but he did not care to invest any money in

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] a market reduction in the operating [illegible] meet competition.

quarter's salary long overdue. Now that the new exchange was completed and the lines all in fine order, any cheap man could "run it," and so he *had* to *go*. And where did he go? Back to the old exchange as an inspector. To be sure he has the satisfaction of seeing the new exchange fast losing its subscribers, and to find that his old exchange has more subscribers than ever it had under his management, and the new manager drawing an increased salary. But the company is lenient and will transfer the inspector to a smaller exchange where he can again serve as manager and regain much that was lost in the weary, wasted months.

F. DE L.

The Real National Issue. Whether you are a Democrat or a Republican, a Popocrat or an out-and-out Populist, don't forget the speech at Delmonico's of the strongest leader the Republicans have today: "Advertisement is an absolute prerequisite to the sale of goods, and your best advertisers are always your enemies. Your friends sometimes go to sleep. Your enemies never do."

F. DE L.

The Carbon Trust. There is a great deal of wind in the talk about the evils that trusts are falsely supposed to cause. For though prices may be slightly increased, following a consolidation or pooling of interests, yet this in turn is usually followed by an output improved either in mechanical finish, or in quality, so that an equivalent return is received for the increased price paid by the consumer. But trusts are fewer in number than the demagogue would have us believe. Thus, the charge that the American Carbon Company is a member of the so-called carbon trust is a difficult charge to prove, and any reference to "its hypocritical love for the best interests of the central station" will be open to the charge of using spiteful language. The man of narrow views may find some credence for such a charge in the statement that carload shipments of the product of the American factory are sent at regular periods to Cleveland, and checks in payment therefor mailed to Noblesville. Even admitting the truth of the statement, what harm can it do? If the consumer has to pay one price for his carbons, is he not likely to select that carbon that gives the best satisfaction, regardless of the locality it comes from? There is too much Popocratic denunciation of trusts, anyway.

F. DE L.

The Hyde Park Telephone Exchange. Hyde Park has a competing telephone exchange, and now peace abideth in the hearts of certain "chronics." Not that a "chronic" ever subscribes for a telephone so long as he can sponge its use, but we all like to rail at the successful, and rejoice at their apparent discomforture. Hyde Park, by the way, is a part - - rather a small part — of the city of Chicago, which fact furnishes the versatile daily molders of public opinion an excellent opportunity to display their ignorance, and thereby further mislead the public on the subject of telephone service and telephone charges by filling much space with comments on the competing exchange in Chicago. The United Telegraph, Telephone and Electric Company, the owner of this new exchange, has installed a small switch board in the rear portion of the ground floor of a single-story building, and claims to have a conditional franchise permitting the placing of wires as far south as the city now extends within the area bounded by State street and the lake. But, unfortunately, it cannot come north of Thirty-ninth street, that is, down-town to the heart of the city. A voluminous list of subscribers gives the rates for business houses at $54; residences, $36 yearly, and contains the names of about one thousand residents congregated within the area of a few blocks. The highest telephone number registered appears to be "No. 500." But this must be a mistake, for telephone No. 241 is registered at the residences of no less than fifty subscribers, and we find No. 450 registered for thirteen different places on opposite sides of Cottage Grove avenue, and at three places on Forty-third street. Then page 19 tells us that a constable on Langley avenue has telephone No. 500 (coming events often cast their shadows before), while page 20 places it over on Forty-third street in an express office. Then page 21 says it's way out on the opposite side of the street, and so on through a dozen pages. Thus we fear that this list will be of slight assistance to the attorneys of the Bell interests should suits for damages be entered against the individual users of infringing telephones. For who is capable of locating these mysterious instruments long enough to secure prima facie evidence? And surely the Bell interests will waste no time in litigation with May and Pearl, Pauline and Ethel, Lizzie and Ada, and the hundred or two children whose names appear in the list of subscribers? Or did the children sign the three-year con- ? Does smack a little of childishness to pay $54 for service

connections to 500 telephones, when for about double that sum service connections to *twenty-two times* that number of telephones can be had. But, of course, no law suit would be thrown in with the latter service. The company claims to have invested more than $50,000, which is quite probable, as a quantity of lead cable has been used in underground circuits. But if a large number of the telephones are of the nickel-in-the-slot type, and have been placed in service without a guarantee on the subscriber's part, then the income of the company is problematical. Especially is this true if the instruments in the business houses also having Bell telephones will be used merely for receiving incoming messages.

FRED DE LAND.

Telephone Competition in Chicago. On August 2, 1894, the Chicago *Tribune* devoted much space to a description of how the so-called telephone monopoly was to be broken down in Chicago — automatically broken down. "No girls would be needed in the exchange, only a few men sitting around ready to oil machinery and answer emergencies." This new company would "have 15,000 subscribers at $60, yielding an income of $900,000." The detailed cost of operation and maintenance was "to be only $290,000, leaving a net profit of $600,000 a year, or about 15 per cent on the investment of $4,000,000." The Harrison people were reported interested, which may account for the later appearance in the "Barter and Exchange" columns of the *Tribune* of advertisements offering to trade Harrison telephone stock for baby carriages, "or anything." Two years later, or to be exact, on August 13, 1896, the financial editor again booms this opposition scheme, and paves the way for further investments by the widow and the fatherless: "The Cosmopolitan Electric Company, which secured a franchise from the city council, is now figuring with an offshoot of the Harrison Company . . . this franchise gives the company the right to construct telephone lines without any further ordinances," etc. Of course there will always be some thoughtless investors, else the infringing telephone shark would long ago have drifted back to his old calling. But the thoughtful will recall the opinion of an attorney quoted in the Chicago *Tribune* of April 6, 1895: "The franchise of the Cosmopolitan Company will not stand the tests of the courts, and I do not think capitalists will be willing to put a lot of money in this franchise

and then have the Supreme Court declare it void about the time a dividend period has been reached." If the editor of the *Tribune* will turn back a few files he will find a paragraph telling his readers that the larger users of telephone service are not crying for competition, but for perfect service — a service of such high character that no opposition can successfully and permanently compete with it. To afford telephone service at lower rates is to win popular applause for the time being; but the practical business man dependent on telephone orders for a large share of his business will consider the *quality* of the service furnished and not the cost. For the loss of one customer through imperfect telephone service may mean a net reduction in income greater than the rental charge for half a dozen telephones. Cheap telephone service necessarily means depreciated telephone service.

FRED DE LAND.

What Fools These Editors Be. After all has been said, is it really the wisest course to advertise Mr. Bryan as thoroughly as the daily press, without regard to political affiliations, is doing? On a far smaller scale this same method of universal belittlement and denunciation was adopted in Chicago when Carter Harrison was nominated for mayor, and every journal except his own strove to defeat his election. But the many evil charges made and the thorough ventilation of his record as a public official started the voters to doing their own thinking, and Mr. Harrison went into office with a majority of 20,000. The presidential campaign of 1844 was also for grand principles, but the "obscure Tennesseean" triumphed over the idolized Henry Clay, the reputed standard bearer of the wealth, the intelligence and the virtue of our country. For so thoroughly did the sanguine friends of Henry Clay advertise the faults and defects of Mr. Polk that when election day came he was known from sea to sea, and was chosen by the people as their chief executive.

FRED DE LAND.

Electrical Engineering

OCTOBER, 1896.

CENTRAL STATION ECONOMICS.*

BY ARTHUR V. ABBOTT, C.E., AND FRANZ J. DOMMERQUE, M.E.

PART II.—CONTINUED.

γ. GAS.

The ideal combustible is fuel in the form of gas. It may be readily transported from place to place, at least over reasonable distances. It may be so completely and thoroughly mixed with air that the theoretical amount necessary for perfect combustion may be practically realized within a fraction of a per cent. Gaseous fuel is absolutely ashless, and its combustion may be controlled, regulated and manipulated far more conveniently and exactly than any other form of combustible. Its action upon the walls of the combustion chamber is less injurious than that of liquid or solid fuel. For production of power by the use of the internal combustion engine, it is possible to combine both the furnace and the prime mover in a single piece of apparatus, entirely eliminating the boiler with its attendant auxiliary appliances, effecting a very notable economy in both capital invested and fuel expended per unit of power produced. By means of gaseous fuel it is possible to obtain a higher calorific intensity than with either solid or liquid combustibles, and combustion may take place at any desired rate up to that of explosive action. Probably the principal objection which can be urged against a gaseous combustible is the amount of space required where storage of large quantities of fuel is necessary.

For purposes of classification, it is convenient to separate gaseous fuels into two parts: natural gas and artificial gas.

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Natural gas embraces all hydrogen and hydrocarbon compounds so volatile as to occur in the gaseous forms in nature, while artificial gas is always produced by operating on solid or liquid fuel by some process of manufacture.

Concurrently with the existence of coal and oil fields, there are occasional localities in which the gaseous products of the great still of nature have been stored in the rocks, and can, by the process of drilling, be obtained from wells in precisely the same manner as petroleum. In fact, natural gas, as such a product is usually denominated, and rock oil are associated. That the natural reservoirs of gas are much more limited in extent and of less frequent occurrence than the coal or oil fields is to be expected, for, from its greater volatility, the gas escapes more easily from the rocky reservoirs, and becoming dissipated in the atmosphere, leaves no trace of its existence. In the eastern portion of the United States, chiefly in New York, Pennsylvania, Ohio and Indiana, the employment of natural gas has received its highest development. This may be chiefly attributed to the existence in this section of the country of numerous local deposits of great magnitude, but partly to an aggregation of manufacturing interests and to the quickness and readiness with which Americans perceive and utilize mechanical possibilities of this nature. The coal and oil fields and natural gas regions are so closely affiliated that it is difficult to separate them, excepting upon maps of a very large scale, and, therefore, the localities indicated in Fig. 1 * as embracing petroleum deposits may be included to represent as well the places where a yield of natural gas may be expected. The distribution of natural gas, both geographically and geologically, has been so thoroughly investigated and carefully studied that, while it is impossible even for the experienced geologist to predict with certainty that in any specified region natural gas will be found, it is comparatively easy to determine the localities in which the improbability of a successful gas well is so marked as to render it utterly inexpedient to attempt boring, and the expense of a well is only justifiable after a favorable opinion of the most expert character.

The earliest and most extensive development of natural gas resources has taken place at the city of Pittsburg. The natural gas consumers in this city may be counted by tens of thousands,

* See page 23, ELECTRICAL ENGINEERING, July, 1896.

while over a thousand of the largest manufacturing enterprises in the world depend solely upon this source of supply for fuel.

The consumption of gas in Pittsburg amounts to from 600 to 1,000 million cubic feet per day, displacing an amount of coal estimated at over ten million tons per annum. According to the eleventh census the distribution of natural gas consumption is indicated in Table No. 36.

TABLE No. 36.—CONSUMPTION OF NATURAL GAS.

	Cubic Feet.
Iron and steel mills	171,500,000,000
Glass works	18,750,000,000
Miscellaneous manufacturing	256,900,000,000
Heating and cooking	62,500,000,000
Pumping oil	7,500,000,000
Operating oil and gas wells	30,000,000,000
Miscellaneous	25,000,000,000
Total	572,150,000,000

Of this amount Pennsylvania consumes 71.5 per cent; Ohio, 17.3 per cent; Indiana, 7.5 per cent, and New York, 1.4 per cent. Numerous pipe lines have been constructed from Pittsburg to the gas-producing regions in the immediate vicinity, and as the pressure of the gas at the wells rises to several hundred pounds to the square inch there is little or no difficulty in conducting supplies of gas over comparatively long distances with a moderate expense for the installation of the gas pipe lines. Probably the chief limitation to the use of natural gas consists in the difficulty of transporting it from place to place, for pipe lines which would be large enough to conduct a sufficient amount of gaseous fuel over distances of considerable magnitude, to supply large manufacturing interests, would be expensive in construction and maintenance, and would be constantly subjected to serious leakage. Within, however, a few score of miles, natural gas distribution may be effected with the greatest economical success.

As petroleum has been found to consist of such a mixture of hydrocarbons belonging to the series $C_n H_{2n+2}$ and $C_n H_{2n}$ as are liquid at ordinary temperature, natural gas includes the hydrocarbons that are commonly volatile. In addition free hydrogen, with traces of carbon monoxide, carbon dioxide, oxygen and nitrogen, are commonly found. The methane or marsh gas series and the ethylene or olefiant gas series, are the hydrocarbons

TABLE No. 37.—PHYSICAL CONSTANTS OF HYDROGEN SERIES.

Name of Hydrocarbons.	Symbol.	Specific gravity referred to hydrogen.	Calorific value by weight.		Calorific value by volume.		Pounds of oxygen required per pound of combustible.	Pounds of air required per pound of combustible.	Cubic feet of oxygen required per cubic foot of combustible.	Cubic feet of air required per cubic foot of combustible.	Products of combustion.	Volumes of products of combustion in cubic feet.
			B. T. U.	Kilocalories.	B. T. U.	Kilocalories.						
Acetylene	C_2H_2	12.97	21850	12143	1600	14030	3.08	13.4	2.5	11.8	H_2O and CO_2	6
Methane (marsh gas).	CH_4	7.985	23500	13100	1007	8480	4	17.4	2	9.52	"	3
Ethylene (olefiant gas)	C_2H_4	13.97	21400	11900	1620	14170	3.43	15	3	14.28	"	4
Ethane	C_2H_6	15	22500	12500	1770	15490	3.73	16.3	3.5	16.66	"	5
Propylene	C_3H_6	21	21250	11800	2479	21700	3.42	15	4.5	21.4	"	6
Benzene	C_6H_6	39	17610	9950	3820	33400	3.08	13.4	7.5	35.71	"	9
Butylene (tretylene)..	C_4H_8	56	19566	10870	3275	28150	3.43	15	6	28.57	"	8

TABLE No. 39.—ANALYSES OF NATURAL GAS FROM DIFFERENT LOCALITIES.

	LOCATION OF WELL.	ANALYSIS BY VOLUME.								ANALYSIS BY WEIGHT.								Calculated Calorific Value in B. T. U. per 1000 cubic feet of gas.	Calculated Calorific Value in B. T. U. per lb. of gas.
		H	CH_4	CO	CO_2	N	O	Heavy* Hydro-carbons.	H_2S	H	CH_4	CO	CO_2	N	O	Heavy Hydro-carbons.	H_2S		
1.	Anderson, Indiana	1.86	93.07	0.73	0.26	3.02	0.42	0.47	0.15	0.22	91.00	1.18	0.70	5.14	0.82	0.82	0.32	1016900	22030
2.	Kokomo, "	1.42	94.16	0.55	0.29	2.80	0.30	0.30	0.18	0.17	91.90	0.93	0.75	4.78	0.58	0.51	0.37	1021850	22040
3.	Marion, "	1.20	93.16	0.60	0.30	3.42	0.55	0.15	0.20	0.15	90.50	1.01	0.91	5.80	1.06	0.26	0.41	1008760	21680
4.	Muncie, "	2.35	92.67	0.45	0.25	3.53	0.35	0.25	0.15	0.28	90.67	0.73	0.68	6.20	0.69	0.43	0.32	1003750	21820
5.	Bloomfield, New York	.....	82.41	.....	10.11	4.31	0.28	2.94	.....	.....	67.00	.....	22.25	6.10	0.45	4.20	.....	925550	16820
6.	Olean, "	.....	96.50	0.50	.....	.....	2.00	1.00	.....	.....	93.90	0.75	.....	.....	3.75	1.60	.....	1018490	22640
7.	Findlay, Ohio	1.64	93.35	0.41	0.25	3.41	0.39	0.35	0.20	0.20	90.84	0.69	0.67	5.83	0.76	0.60	0.41	1010580	21830
8.	Fostoria, "	1.89	92.84	0.55	0.20	3.82	0.35	0.20	0.15	0.23	90.47	0.94	0.69	6.50	0.52	0.34	0.31	100900	21730
9.	St. Mary's, "	1.94	93.85	0.44	0.23	2.98	0.35	0.20	0.21	0.24	91.73	0.76	0.62	5.20	0.68	0.34	0.43	1019720	21980
10.	Barns Well, near St. Ive, Butler Co., Pa	6.10	75.54	trace	0.34	.....	.....	18.12	.....	0.70	69.15	trace	0.85	.....	.....	28.30	.....	1117100	22850
11.	Cherry Tree, Indiana Co., Pa	22.50	60.27	.....	2.28	7.32	0.83	6.80	.....	3.26	62.70	.....	6.52	13.40	1.72	12.40	.....	841500	19270
12.	Grapeville, Westmoreland Co., Pa	7.05	35.08	0.22	0.58	27.87	0.16	29.04	.....	0.63	25.50	0.27	1.16	35.50	0.24	36.70	....	892950	14270
13.	" " " "	24.56	14.93	trace	trace	18.69	1.22	40.60	.....	2.47	12.00	trace	trace	26.10	2.00	57.30	.....	924500	16460
14.	Harvey Well, Butler Co., Pa	13.50	80.00	trace	0.66	....	....	5.72	.....	1.83	86.50	trace	1.95	.....	.....	10.80	.....	997500	23800
15.	Leechburg, Westmoreland Co., Pa	4.79	89.65	0.26	0.35	.....	....	4.39	.....	0.60	90.29	0.44	0.97	.....	.....	7.70	.....	1046380	23380
16.	Pittsburg, Pa	9.64	57.85	1.00	.....	23.41	2.10	6.00	.....	0.86	41.50	1.25	.....	45.94	3.00	7.45	.....	747520	12000
17.	" "	14.45	75.16	0.30	0.30	2.89	1.20	5.40	.....	2.09	83.09	0.58	0.91	0.50	2.43	10.40	.....	947730	23250
18.	" "	20.02	72.18	1.00	0.80	.....	1.10	4.30	.....	2.83	81.50	1.97	2.60	.....	2.60	8.50	.....	916620	22840
19.	" "	26.16	65.25	0.80	0.60	.....	0.80	6.30	.....	3.88	77.50	1.66	1.96	.....	1.90	13.10	.....	898730	23310
20.	" "	29.03	60.70	0.58	.....	....	0.78	8.90	.....	4.40	73.50	1.24	.....	.....	1.96	18.90	.....	902000	23900
21.	" "	35.92	49.58	0.40	0.40	.....	0.80	12.90	.....	5.6	61.95	0.88	1.37	.....	2.00	28.20	.....	892370	23620
22.	" "	22.00	67.00	0.60	0.60	3.00	0.80	6.00	.....	3.40	83.20	1.30	2.10	6.60	2.10	1.30	.....	895050	22030
23.	Caspian region, Russia	.....	92.24	.....	3.50	.....	....	4.26	.....	.....	84.52	.....	8.60	.....	...	6.88	.....	1062000	21570
24.	" " "	...	97.54	.....	2.47	.....	....	.....	....	.....	93.35	.....	6.65	.....	....	.....	.....	1050000	22200
25.	" " "	.....	95.56	.....	4.44	.....	....	.....	.....	.....	88.00	.....	12.00	.....	....	.....	.....	1030000	20900
26.	Aspheron Peninsula, Russia	0.34	92.49	.....	0.93	2.13	....	4.11	.....	0.04	87.38	.....	2.43	3.35	....	6.80	.....	1061670	22280
27.	" " "	0.98	93.09	.....	2.18	0.49	....	3.26	.....	0.16	88.14	.....	5.55	0.83	....	5.32	.....	1063360	22170
28.	Pechelbronn, Germany	.....	77.03	3.5	3.6	8.9	1.8	4.8	.....	.....	64.00	5.00	8.20	12.90	3.00	6.90	.....	908200	16900

*NOTE.—The calorific power is approximate only as the gases of the series $C_n H_{n+2}$ are combined under the heading "Heavy Hydrocarbons." The calorific value of ethylene has been used in calculation, as usually forming the bulk of the heavy hydrocarbons.

usually encountered in the largest quantity. The first three members of each series are the ones of chief occurrence, the physical properties of which will be found in Table No. 37.

The constitution of natural gas varies somewhat, but it may without serious error be considered to be chiefly composed of marsh gas, ethylene and hydrogen. The ordinary ranges in composition are indicated in Table No. 38.

TABLE No. 38.—RANGES OF COMPOSITION OF NATURAL GAS.

Hydrogen	5 to 20 per cent.
Nitrogen	1 " 12 " "
Marsh gas (Methane) CH_4	60 " 80 " "
Ethane C_2H_6	1 " 8 " "
Propane C_3H_8	0 " 2 " "
Heavy hydrocarbons (Ethylene series).	0 " 40 " "
Carbon dioxide CO_2	.3 " 2 " "
Carbon monoxide CO	Traces.

From this table it will appear that natural gas is exceedingly rich in the methane and ethylene series, and that on the average it may be assumed to yield about 1,000 B. T. U. per cubic foot of gas, or 20,000 B. T. U. per pound. An accurate and detailed statement of the composition of natural gas as obtained in various localities may be obtained by consulting Table No. 39 — Analysis of Natural Gas from Different Localities.

As an aid to the accurate determination of the calorific power of natural gas of known composition, reference may be made to Tables Nos. 40 and 41, by means of which the number of thermal units in any natural gas of known composition may be rapidly ascertained. The tables are arranged to comprise the chief combustibles, namely: hydrogen, carbon monoxide, marsh gas and the heavy hydrocarbons. The hydrogen content, in percentage, will be found upon the center vertical line at the right hand, while the percentage of the other remaining constituents is to be sought for on the three sets of diagonal lines extending in succession through the body of the table from right to left. An example will indicate the use of the table more conspicuously than any other manner. Thus, selecting from Table No. 39 as an example No. 22, the amount of hydrogen is seen to be 22 per cent; carbon monoxide, 60 per cent; marsh gas, 67 per cent; heavy hydrocarbon, 6 per cent; all by volume. Select on the hydrogen line of Table No. 40 the number 22, representing the amount of

hydrogen. Follow a horizontal to the right to an intersection with the carbon monoxide diagonal through 0.60 per cent, then a vertical downward to an intersection with the methane diagonal through 67 per cent, thence horizontal to the left to the intersection with the heavy hydrocarbon diagonal through 6 per cent, and from this point a vertical upward to the B. T. U. scale, finding 895 as the calorific value per unit volume of gas in B. T. U. The dotted line and the arrows show the course to be pursued. While Table No. 40 thus serves to determine the calorific power from the volumetric analysis, Table No. 41 may be used for calorific power when the composition by weight is given. The construction and use of this table is exactly similar to that of Table No. 40, and the same example is used to exemplify the operation of the table.

To those manufacturers who are so fortunately circumstanced as to be geographically within a natural gas field, the fuel question is hardly a subject of discussion; but relatively few there are that are so happily situated, and under the pressure of competition it becomes of vital importance to determine whether or not some process of treatment applied to raw fuel for the purpose of transforming it from the solid or liquid to the gaseous state will effect a notable economy in the final cost of the finished product. That in some cases such transformation is eminently to the interest of the manufacturer can be abundantly substantiated in the entire change in metallurgical practice within the last quarter of a century. A steel manufacturer who would now attempt the reduction of ore by the means of a solid fuel would utterly fail in competition with those who operate with the same fuel transformed into a combustible gas, for by the use of gas the metallurgist can accomplish in some cases the same result with but one-sixth of the quantity of fuel that would be required in the solid state.

The consideration of this problem, however, always involves the balance of certain loss against an expectant gain, for all processes of transformation by means of which the solid or liquid fuel is changed into a gas are inevitably accomplished only at the sacrifice of a portion of the calorific power of the fuel itself. But the convenience and facility of control presented by the gaseous fuel in comparison with that of either the liquid or solid, is frequently so great that such transformation is the only possible solution for

the manufacturer to adopt; yet it should always be borne in mind that, notwithstanding the glittering inducements exhibited by exploiters of new processes for gasification, all such operations must necessarily involve a sacrifice of a portion of the fuel, so that no matter how glowing may be the claims of would-be inventors of processes that are guaranteed to give "*More heat than the original coal contained*," a loss more or less great is always inevitable and inexorable. Under exceptionally favorable circumstances, it is possible to realize with artificial gas, 90 per cent of the heat energy of the fuel employed in its production. Commercially speaking, 80 per cent would be considered first-class practice, while it is probable that in the majority of existing fuel gas plants from 65 to 75 per cent of the original calorific power of the fuel employed is all that is, on the average, obtained.

For convenience in classification it is the practice to divide the artificial processes of fuel gasification into three kinds, depending upon the method of gas manufacture:

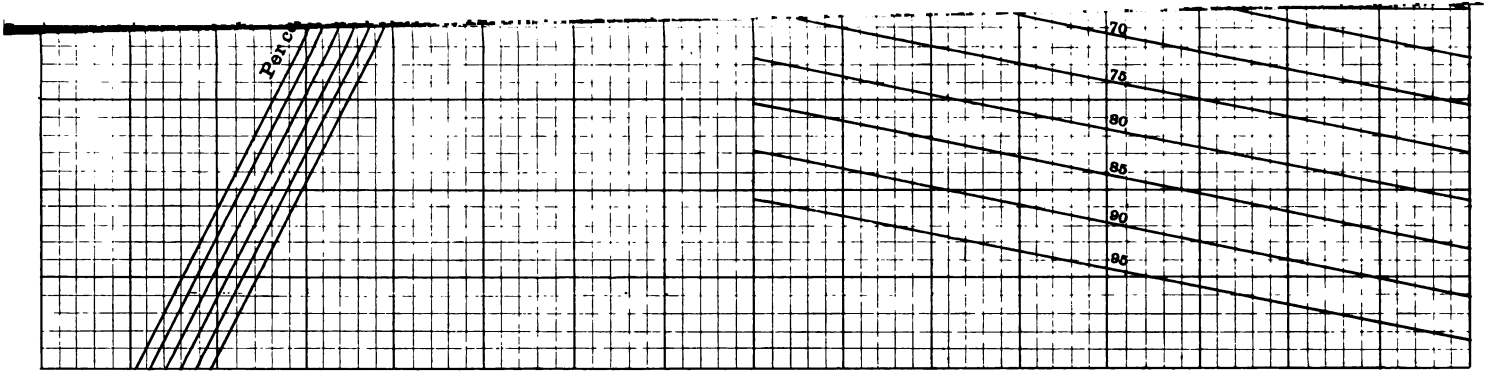
First, The Distillation Method,

Second, The Producer Process,

Third, The Water Gas Plan.

The first method by distillation is that which is adopted in the manufacture of illuminating gas, and consists in subjecting such varieties of coal as contain very large quantities of volatile hydrocarbons to destructive distillation in a closed retort. The manufacture of gas for the purpose of urban illumination has been a commercial occupation for a hundred years. The richer varieties of bituminous coal usually denominated "Cannel Coals" are placed in a closed retort and intensely heated. The more volatile constituents are expelled and passing through the heated retort come in contact with the intensely heated walls and red-hot coke, and are decomposed to become essentially fixed gases. Upon the complete expulsion of the volatile portion of the coal, the residual carbon remains in the retort in the form of coke for subsequent utilization, as a byproduct. To purify the gas thus obtained from tarry and ammoniacal vapors which would otherwise condense and clog the distributing mains, it is necessary to resort to elaborate and expensive processes of washing and scrubbing, passing the gas through a series of coolers and water jets and exposing it to the action of quicklime in order to render it ready for delivery to the consumer.

TABLE No. 40.—FOR DETERMINATION OF CALORIFIC VALUE OF NATURAL GAS BY VOLUME.



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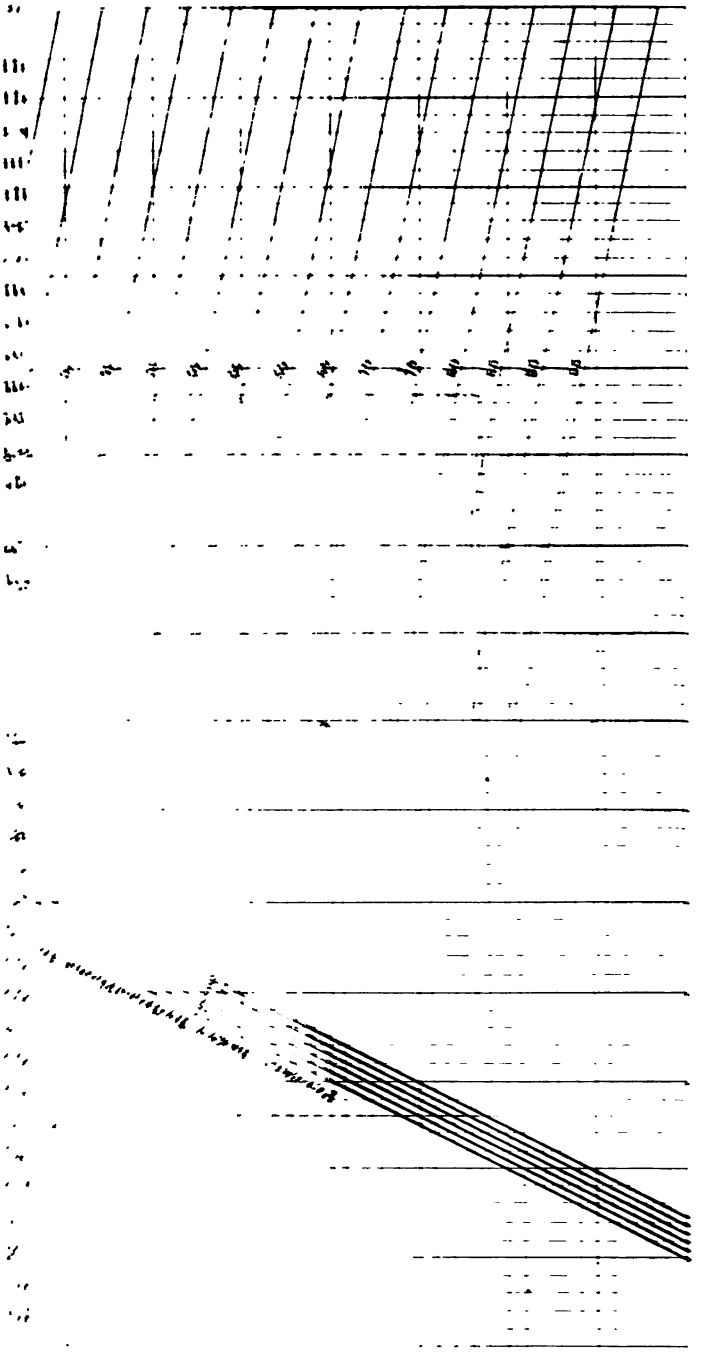


A great many theories have, from time to time, been advanced to explain the reactions of distillation, but Prof. E. A. Mills has endeavored to prove that a very simple relation between the fixed carbon and the hydrocarbons in gas and coal is sufficient to account for the changes that take place. He assumes that C_3 is the fundamental unit, and by employing collocations of symbols, he contrives to fit theory to practical results. Excluding the unimportant constituents, coal may be represented by $C_{24}H_{18}O$, and destructive distillation may take place as represented in equation 23.

$$\underset{\text{(coal)}}{2\,C_{24}H_{18}O} = \underset{\text{(fixed carbon)}}{33\,C} + \underset{\text{(gas and tar)}}{C_{15}H_{34}O} + \underset{\text{(water)}}{H_2O} \qquad (23)$$

According to this reaction 100 parts of coal should yield 61.5 carbon, 35.7 gas and tar, and 2.8 parts water. Actual practice shows about 61.5 parts coke and 38.5 parts volatile matter.

Coal gas, as would naturally be expected, varies in composition, depending upon the coal employed and the processes used. The average composition is shown in Table No. 42.

TABLE No. 42.—AVERAGE COMPOSITION OF COAL GAS.

Hydrogen	from 42.0	to 53.0	per cent by volume.	
Methane	" 32.0	" 39.0	"	"
Carbon monoxide	" 3.0	" 9.0	"	"
Hydrocarbons —				
Gaseous	" 2.5	" 4.5	"	"
Light (condensable vapor)	" 0.5	" 1.2	"	"
Carbon dioxide	" 1.1	" 1.8	"	"
Nitrogen	" 1.0	" 5.0	"	"
Hydrogen sulphide	" 1.2	" 2.0	"	"
Ammonia	" 0.5	" 0.9	"	"
Cyanogen	" 0.07	" 0.12	"	"
Carbon disulphide	" 0.025	" 0.035	"	"

To attain the requisite illuminating power, only the richest and consequently the rarest and most expensive of soft coals are suitable for this process. As only from 15 to 30 per cent by weight of the coal passes into the gas thus manufactured, the process is manifestly too expensive to afford a gas that can compete as a fuel with other forms of solid and liquid combustibles. The quantity of gas obtained per unit weight of coal varies both with the kind of coal employed and the process used. Table No. 43 — Illuminating Gas Yielded per Ton of Coal — contains the best obtainable statistics bearing on this point.

TABLE No. 43.—ILLUMINATING GAS YIELDED PER TON OF COAL.

Description of Coal.	Cubic feet of gas yielded per ton of coal of 2240 pounds.	Weight of gas in pounds per ton of coal of 2240 pounds.	Cubic feet of gas from 1 pound of coal.	Weight of gas in pounds per pound of coal.	No. of cubic feet in 1 pound of gas at ordinary pressure and temperature.
Arniston	12,600	606	5.620	.2703	.....
Bickerstaff, Liverpool	11,424	415	5.096	.1851	....
Boghead	15,000	866	5.700	.3866	17.32
Capeldrae	14,400	638	6.423	.2845	.....
Derby's Deep Main	9,400	308	4.197	.1375	30.52
Derby's Soft Coal	7,500	303	3.345	.1351	.....
Forest of Dean	10,133	279	4.159	.1244	.....
Garesfield	10,500	321	4.683	.1432	.....
Incehall	11,400	461	5.090	.2058	24.73
Leeds	6,500	264	2.899	.1177	.....
Lesmahago Cannel	11,312	638	5.050	.2848	17.73
Neath, S. Wales	11,200	401	5.000	.1790	27.93
Newcastle	11,648	423	5.195	.1886	.....
Newcastle	11,492	398	5.130	.1776	28.87
Pelaw	11,424	389	5.096	.1735	.....
Pelton	11,424	387	5.096	.1726	.....
Powell	10,165	357	4.529	.1592	.....
Scotch Parrot	9,500	235	4.281	.1048	.....
Staffordshire	10,467	302	4.673	.1348	34.66
Welsh	11,424	645	5.096	.2877	.....
W. Bromwich	6,500	226	2.902	.1009	28.76
Wigan	11,400	461	5.085	.2056	.....
Wigan	9,500	357	4.241	.1594	26.61
Wigan	9,408	344	4.200	.1536	27.35

From the figures of this table it is perceived that on the average one ton of coal may be expected to produce about 10,000 cubic feet of gas, weighing about 350 pounds, and that one pound of coal should be credited with five cubic feet of gas. As the manufacture of city gas is usually undertaken to provide an illuminant, high candle-power is the chief requisite sought, irrespective of heating effect. The illuminating power of a gas flame depends on the presence of the requisite amount of carbon, which though to the eye is in the gaseous form, is nevertheless supposed in reality to be solid, and owing to the heat developed by the combustion of the hydrogen constituents of the gas is raised to a high degree of incandescence, in precisely the same fashion that the carbon filament of an electric lamp is heated to luminosity by the current. To obtain, therefore, a good illuminating gas it is

essential to preserve a careful balance between the relative proportions of the hydrogen and carbon constituents. If the carbon is in excess the flame will be smoky and give rise to dissatisfaction from an unusual deposit of soot. On the contrary, if hydrogen be in excess, a very hot flame of high calorific power can be obtained, but with little or no illuminating ability. This result is usually the error into which gas manufacturers are most prone to fall, and for which two paths for correction are open. Either the gas may be properly enriched by the maker, by injecting therein some rich volatile hydrocarbon such as the heavier grades of petroleum, and fixing the same to prevent subsequent condensation by passing the vapor-loaded gas over red-hot carbon; or by supplying the burner of the consumer with some device that may be heated by the nonluminous flame to the desired incandescence. This is the object of the well-known Welsbach burner, in which a cone of magnesia, or other alkaline earth, is heated to whiteness by means of a water gas that is chiefly hydrogen, and consequently yields alone almost a nonluminous flame. To enrich all the gas delivered by the manufacturer, restricts its use to that of illumination, as the process of enriching not only loads the gas with so much expense as to render it prohibitive as a fuel, but also detracts largely from its flexibility as a combustible. By means of the other method a very cheap gas may be supplied by the manufacturer, which by the consumer may be applied indiscriminately to the production of either light or heat. But illumination can only be secured by the use of a complicated and expensive burner, which can as yet hardly be said to be entirely satisfactory. Yet this direction appears at present to be a promising avenue, attracting installations of magnitude for the distribution of both light and power.

Coal gas, as usually manufactured, varies considerably in composition, the hydrogen content and the relative properties of the methane and ethylene constituents changing with the kind of coal employed. In Table No. 44 — Composition of Illuminating Coal Gas — will be found both volumetric and gravimetric analyses from a number of the principal manufacturers.

As the coal employed in the manufacture of illuminating gas is the most expensive variety, as but about one-third of the carbon is gasified, and as the process of purification still further loads the output with expense, it is evident that it is only under

TABLE No. 44.—COMPOSITION OF ILLUMINATING COAL GAS

	GAS MANUFACTURED AT.	ANALYSIS BY VOLUME.							ANALYSIS BY WEIGHT							Calorific Value in B.T.U. per cubic foot	Calorific Value in B.T.U. per lb.
		H	CH_4	CO	CO_2	N	O	Heavy Hydro carbons.	H	CH_4	CO	CO_2	N	O	Heavy Hydro carbons		
1.	Cologne	50.00	34.40	5.20	....	....	..	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.	Bonn	30.80	43.12	4.00	3.02	4.68		4.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.	Chemnitz	51.29	36.45	4.45	1.08	1.43	...	4.90	[illegible]	[illegible]	[illegible]	[illegible]	4.38	[illegible]	[illegible]	[illegible]	[illegible]
4.	Heidelberg	44.00	38.40	5.73	0.37	4.23	....	7.27	[illegible]	[illegible]	[illegible]	[illegible]	1.30	[illegible]	[illegible]	[illegible]	[illegible]
5.	Dresden	48.70	33.40	8.00	1.50	4.00	1.40	3.00	8.40	[illegible]	[illegible]	[illegible]	5.84	[illegible]	[illegible]	[illegible]	[illegible]
6.	Hanover	46.27	37.55	11.19	0.81	1.0	.....	3.17	[illegible]	51.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7.	Paris	50.10	35.10	6.30	1.50	2.00	0.50	5.00	0.13	47.00	15.7	5.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8.	Birmingham (from coal)	40.23	39.00	4.05	1.50	10.10	0.30	4.00	0.41	47.5	8.30	8.17	1.50	[illegible]	[illegible]	[illegible]	[illegible]
9.	Brighton "	51.62	38.15	4.14	0.03	2.00	0.23	3.00	10.35	61.00	11.80	[illegible]	5.8	[illegible]	[illegible]	[illegible]	[illegible]
10.	Bristol "	44.57	40.7	4.77	....	5.11	0.27	4.58	[illegible]	56.40	11.12	[illegible]	4.0	[illegible]	11.00	[illegible]	[illegible]
11.	Edinburgh (from cannel)	33.24	42.93	6.61	0.35	3.64	1.00	12.23	4.15	48.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12.	Glasgow "	39.18	40.26	7.14	0.29	3.07	0.00	10.00	[illegible]	[illegible]	18.40	0.18	[illegible]	1.15	[illegible]	[illegible]	[illegible]
13.	Gloucester (from coal)	48.80	38.25	4.64	0.03	2.73	0.51	4.05	0.10	57.11	[illegible]	0.12	7.10	1.54	[illegible]	[illegible]	[illegible]
14.	Ipswich "	43.26	38.73	2.46	0.06	10.81	0.19	4.53	7.15	51.00	5.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15.	Leeds (from cannel)	40.23	42.74	5.02	0.34	4.32	0.07	7.28	6.46	54.80	11.23	[illegible]	9.00	[illegible]	10.15	[illegible]	[illegible]
16.	Liverpool "	36.44	44.28	3.30	1.70	0.10	0.19	7.90	5.10	52.00	7.12	[illegible]	[illegible]	0.40	[illegible]	[illegible]	[illegible]
17.	London Gas Light & Coke Co. (ft. coal)	47.99	37.64	3.75	.....	5.95	0.06	4.41	8.72	54.63	0.53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18.	South Metropolitan (from coal)	53.14	36.55	4.11	0.09	3.19	..	2.92	10.80	59.50	11.60	0.40	9.10	[illegible]	[illegible]	[illegible]	[illegible]
19.	Manchester (from cannel)	45.58	34.90	6.64	3.67	2.46	..	6.46	7.30	45.10	14.80	12.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20.	Newcastle-on-Tyne (from coal)	50.50	36.71	3.37	0.28	5.20	0.23	3.62	9.00	55.80	9.00	1.17	11.10	[illegible]	[illegible]	[illegible]	[illegible]
21.	Newcastle, Staffordshire "	46.31	39.01	3.74	0.08	6.22	0.11	4.53	8.20	55.23	9.30	0.31	15.23	0.11	[illegible]	[illegible]	[illegible]
22.	Norwich "	53.79	36.11	3.49	0.27	3.03	0.14	3.26	11.10	59.30	9.80	1.32	8.76	0.46	[illegible]	[illegible]	[illegible]
23.	Nottingham "	45.52	39.66	5.63	0.81	2.51	0.24	5.63	7.92	55.23	13.60	3.08	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	Preston (from cannel)	43.95	39.33	4.62	0.84	4.79	0.25	6.22	7.32	57.40	10.80	3.06	11.16	[illegible]	[illegible]	[illegible]	[illegible]
25.	Redhill (from coal)	48.18	39.41	3.41	0.74	3.37	0.49	4.49	8.90	57.80	8.83	2.07	8.16	1.44	[illegible]	[illegible]	[illegible]
26.	St. Andrew's (from cannel)	36.63	42.13	5.16	2.73	2.83	0.48	10.04	5.24	48.10	10.30	8.67	5.70	1.10	20.00	[illegible]	[illegible]
27.	Sheffield "	43.05	43.05	4.72	0.24	2.56	0.10	6.28	7.35	58.80	11.30	0.91	6.12	0.27	15.00	[illegible]	[illegible]
28.	Southampton (from coal)	53.59	38.15	4.14	0.03	2.07	0.23	3.76	10.00	60.80	11.53	0.13	5.70	[illegible]	10.00	[illegible]	[illegible]
29.	Hoboken	39.50	37.30	4.30	2.70	8.20	1.40	C_2H_4 5.85 C_nH_n 0.75 C_2H_4 7.40	5.72	40.33	8.60	8.00	16.83	[illegible]	C_2H_4 14.90 C_nH_n 1.30 C_2H_4 11.00	[illegible]	[illegible]
30.	Boston (Bay State Gas Co.)	36.60	17.20	25.80	3.20	3.40	....	C_2H_4 3.70 C_nH_n 3.70	3.76	11.00	36.00	[illegible]	4.96	[illegible]	C_2H_4 7.98 C_nH_n 14.70	[illegible]	[illegible]
31.	Cleveland (Eastside Co.)	34.80	28.80	10.40	0.20	14.20	0.40	C_2H_4 9.50 C_nH_n 1.70	4.27	38.10	17.01	0.34	11.00	[illegible]	C_2H_4 16.30 C_nH_n 8.10	[illegible]	[illegible]
32.	Philadelphia (Nat'n'l Heat & Power Co.)	35.25	19.85	19.04	4.20	8.05	0.63	C_2H_4 10.95 C_nH_n 1.94	3.87	17.50	9.51	10.40	12.40	[illegible]	C_2H_4 16.8 C_nH_n 8.12	[illegible]	[illegible]
33.	Boston	47.49	38.67	6.74	1.04	0.85	..	C_2H_4 5.21	8.49	55.35	16.90	4.08	2.13	..	C_2H_4 13.05	631.0	21729
34.	Cincinnati	45.85	39.26	4.78	0.82	3.71	0.41	C_2H_4 5.17	7.70	46.00	11.00	3.00	8.70	11.00	C_2H_4 12.00	[illegible]	[illegible]

TABLE No. 45.—COST OF ILLUMINATING GAS AND RELATIVE COST OF GAS AND COAL PER 1,000 B. T. U.

GAS MADE AT	Price per 1,000 cubic feet, charged during 1893, in dollars.	Cost of gas per 1,000 B. T. U. (coal giving 10,000 cubic feet of gas per ton of 2,240 pounds) in cents.	GAS MADE AT	Price per 1,000 cubic feet, charged during 1893, in dollars.	Cost of gas per 1,000 B. T. U. (coal giving 10,000 cubic feet of gas per ton of 2,240 pounds) in cents.	Price of coal per ton of 2 240 pounds (giving 14,000 B. T. U. per pound) in dollars.	Cost of coal per 1,000 B. T. U. in cents.
Cleveland	$0.80	0.034	Denver, Col	$1.50	0.063	$2.25	0.00745
Boston	1.00	0.0425	Detroit	1.50	0.063	2.50	0.0082
Milwaukee	1.00	0.0425	Philadelphia	1.50	0.063	2.75	0.00895
Pittsburg	1.00	0.0425	Kansas City	1.60	0.068	3.00	0.0097
St. Louis	1.18	0.05	Minneapolis	1.60	0.068	3.25	0.01045
Buffalo	1.20	0.051	St. Paul	1.70	0.072	3.50	0.0112
Baltimore	1.25	0.053	San Francisco	2.00	0.085	3.75	0.01195
New York	1.25	0.053	Helena	2.50	0.103	4.00	0.0127
Brooklyn	1.25	0.053	Salt Lake City	2.50	0.103	4.25	0.01345
Chicago	1.25	0.053	Leadville, Colo	2.75	0.117	4.50	0.0142
Providence	1.25	0.053	Sacramento, Cal	3.00	0.127	4.75	0.01495
Washington	1.25	0.053	San Jose, Cal	3.00	0.127	5.00	0.0157

dust, wooden refuse of all descriptions, straw, stubble, the bagasse of sugar plantations, tan bark, and many other by-products containing hydrocarbons are useless as fuels in the ordinary sense of the word, and may, therefore, be obtained at proportionately moderate cost. Although impossible as fuels upon common grates, all such carbonaceous refuse may by means of appropriate apparatus be gasified, and the resulting gaseous fuel be utilized to great advantage. In practice, the cheaper and poorer varieties of coal have been chiefly relied upon to manufacture gas of this description.

The producer, as Dr. Siemens happily termed his apparatus, is a circular furnace shaped somewhat after the fashion of a large crucible, as indicated in Fig. 3. A circular iron casing *X*, of

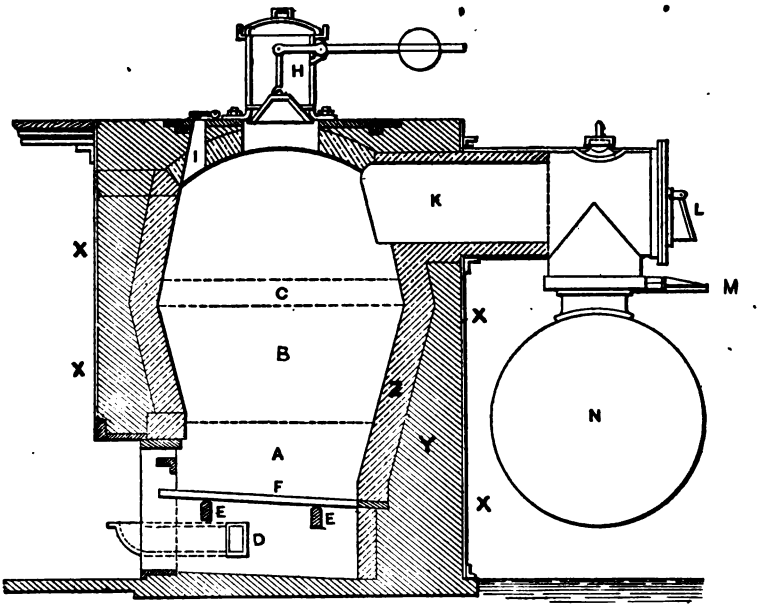


FIG. 3. — SIEMENS PRODUCER.

heavy plate stiffened with angles, forms the framework of the furnace supporting an interior shell of red brick *Y*; this is succeeded by the furnace lining proper *Z*, built of fire brick, in the shape of two inverted truncated cones. At the base of the lower cone two bearing bars *E E* support the grate bars *F* that lie

[illegible]

[illegible] the [illegible] of the [illegible] is [illegible] while in [illegible] the [illegible] of the [illegible] may be [illegible] and [illegible] [illegible]. The gas is [illegible] [illegible] through the [illegible] of the gas main [illegible] [illegible] a number of producers the danger of [illegible] [illegible] for the purpose of cleaning.

When [illegible] the action of the producer is [illegible]

Upon the grate [illegible] a very deep bed of coal is placed, sometimes [illegible] feet in thickness, and the supply of air is so [illegible] as to [illegible] complete combustion. After a short time [illegible] accumulate on the top of the grate bars, which are allowed to remain till a deep layer protects the producer from loss by radiation into the ash pit; the ash bed further serves to heat the air supplied for combustion.

As the hot air filters upward through the ash bed it comes in contact with the first layers of unburned coal and combustion starts, the coal absorbing essentially all the oxygen from the air and burning completely to carbon dioxide (CO_2), as indicated in the accompanying equation, in which air is represented by the not strictly accurate symbol ($O + 3N$):

$$C + 4(O + 3N) = CO_2 + 6N \qquad (24)$$

The carbon dioxide thus formed is presently brought in contact with the upper layers of the coal bed that are intensely hot from the heat evolved from the combustion beneath. In the upper part of the producer there is no free oxygen and hence a second reaction takes place, the incandescent coal robbing the carbon dioxide of one atom of oxygen and reducing it to carbon monoxide, as is indicated by the following equation:

$$CO_2 + C = 2CO + 6N \qquad (25)$$

Turning to Table No. 11 Fuel Reactions*—for the detailed reactions it is seen that 1 pound of carbon burned to carbon monoxide requires 2.38 pounds of air, making 2.33 pounds of carbon monoxide mixed with 4.47 pounds of nitrogen. The original pound of carbon would therefore be converted into 2.3 pounds of combustible gas of which nitrogen forms 65.75 per cent. by weight and carbon monoxide 34.25 per cent. Volumet-

[illegible]

rically, at 62° Fahr. there would be 20.01 cubic feet, or 24 9 per cent of carbon monoxide and 60.55 cubic feet or 75.1 per cent nitrogen, giving a total of 80.56 cubic feet. Usually the gas would leave the producer at nearly a red heat or at upward of 1,000° Fahr. At this temperature there would be 55.9 cubic feet of carbon monoxide and 168 cubic feet of nitrogen, yielding a total of 224 cubic feet. By the combustion to carbon monoxide, 4,450 B. T. U. (2,470 calories) out of a possible total of 14,500 B. T. U. (8,055 calories) or 30.6 per cent of the calorific power of the unit pound of coal is developed in the producer, leaving 10,050 B. T. U. (5,585 calories) or 69.4 per cent of the heating value of the coal as the calorific power of the resulting gas. A large proportion of the 4,450 B. T. U. (2,470 calories) developed in the producer is expended in raising the temperature of the gas as it is manufactured, and if the gas can be used immediately on its exit, most of this heat can be secured and usefully employed, while the balance is inevitably lost by radiation from the walls of the furnace and in the sensible heat carried off in the escaping gas. If, however, the gas must be stored or transported long distances in unprotected pipes, all of this energy may be irretrievably wasted so far as the useful effect is concerned. Some waste of fuel will also occur due to loss of coal unconsumed, through the grate bars, and a portion of the carbon dioxide will escape reduction. These wastes may, respectively, vary from ½ per cent to 5 per cent for the first, and from 2 to 10 per cent for the second. Thus it appears that from the standpoint of efficiency, the producer may yield as a low limit about 55 per cent of the calorific power of the fuel employed when badly managed, but under skillful treatment the efficiency may rise to 85 or 90 per cent. Therefore, in a skillfully operated producer the resulting gas should consist of carbon monoxide and nitrogen, and the skill necessary in operation lies in the requisite adjustment of the supplies of air and coal so all the fuel shall be burned without loss through the grate bars; all the free oxygen shall be absorbed from the air supplied, and all the carbon dioxide shall be reduced to carbon monoxide.

To this end considerable care must be employed in adjusting the relative proportions of air and coal supply, and in regulating the thickness of the fuel and ash beds. If the ash bed is too thin, coal will drop unconsumed through into the ash pit and in

addition much loss experienced in heat radiated from the glowing carbon of the bottom of the fire. On the other hand, if the ash bed is too thick while loss through the grate bars and radiation are prevented, it is difficult to supply the requisite quantity of air to the fuel without resorting to a powerful and consequently expensive air blast. Similarly the thickness of the burning coal must be such as to completely absorb all free oxygen and yet not too great to impede air circulation, while in the superincumbent layers of fuel all the carbon dioxide must be reduced to carbon monoxide.

In case the producer is fed with bituminous coal the volatile hydrocarbons are here distilled and decomposed into fixed gases, exactly in accordance with the process which takes place in the retort of an illuminating gas works; so, the thickness of the upper fuel bed depends, not only upon the amount of carbon dioxide to be reduced, but on the kind of fuel employed, and the amount of volatile constituents. In addition, in the upper fuel layers, the hot gases of the producer are somewhat cooled by absorption of heat contributed to fresh fuel, and a portion of the heat evolved by the primary combustion utilized to raise the temperature of fresh supplies.

Turning again to Fig. 3, the interior of the producer may be divided into three parts, or zones, in reference to the state of the fuel in each location. Thus, the lower portion, *A*, will be chiefly ash and may be denominated "the ash zone." Above the ash zone the greater proportion of fuel will be on fire and, hence, the portion *B* may be termed "the combustion zone," while the upper layers of fuel at *C* are called "the distillation zone." While in the illustration the separate zones are indicated by sharp lines, such is not the case in practice, for one insensibly fades into the other by imperceptible gradations. The complete distillation of the coal occurs only after prolonged exposure to a very high temperature, and lumps of coke may pass completely through the fuel bed almost unconsumed. Thus, there will be partially distilled coal in the combustion zone and unburned coke in the ash region. Also a portion of the gas evolved in the upper coal layers will escape the fixing process of exposure to incandescent carbon. Hence in the producer there will occur a complicated series of decompositions and recompositions in which time and temperature are vital factors. A hot and deep fire

usually produces the most favorable results; but even ten feet of incandescent coke will not reduce all the carbon dioxide, and a fraction of a per cent of oxygen will escape absorption in the thickest practical fire. Under favorable circumstances the product of a carefully operated producer will not exhibit more than one-half of 1 per cent of oxygen, or above from 2 to 3 per cent of carbon dioxide, but so good results can only be gained by careful stoking, as there is a great tendency for the fire to burn unequally, allowing air jets to pass either through the body of the fuel or to creep upward between the coal and the fire brick. Not only does poor firing decrease the producer efficiency by yielding a poor quality of gas, but the dilution of the product by additional quantities of nitrogen and carbon dioxide has a much more serious effect upon the quality of the resulting gas than the mere percentage of their presence would indicate. Further, lack of stoking seriously hazards the apparatus itself, for if air jets are allowed to form, combustion in the immediate neighborhood is enhanced and the ashes are likely to fuse into unmanageable masses of clinkers, which may adhere in a destructive manner to the lining of the furnace, or even corrode or destroy the fire brick itself.

In considering the action of the Siemens producer, it has been assumed that the fuel consisted of pure carbon, and that the office of the producer was simply that of converting the carbon into carbon monoxide. Such would essentially be the case when hard anthracite or coke from gas works formed the fuel. Neglecting the losses by radiation from the furnace, unconsumed fuel and sensible heat carried off by the gas manufactured, it is interesting to trace the operation of the producer under such varying conditions as may reasonably be expected to obtain in practice. Such an analysis is exhibited in Table No. 46—Efficiency of Air-Anthracite Producer.

For fuel, Beaver Meadow anthracite is predicated, and the percentage of unreduced carbon dioxide varied from 2 to 10 per cent. One unit weight of fuel is used and the results of the producer carried out in full. The salient features developed by the table are the large quantities of unconverted nitrogen that the gas contains, and the rapid decrease in efficiency with a rise in the percentage of carbon dioxide, particularly emphasizing the necessity of care in firing. From the figures here given it will

[illegible] ANTHRACITE PRODUCER

[illegible] Pennsylvania No. [illegible]

[illegible] Volatile matter:

[illegible] Ash: Thermal Units per pound.

	[illegible] lb.	[illegible] lb.	[illegible]	Volumetric analysis (dry)	Volumetric analysis (moisture substitute)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	100.00	100.00
Calorific power in 1 lb. of coal			13535		
Efficiency of producer, 61.8%					
5 Bar Pitts.					
[illegible] C burned to CO_2. 512 lbs. C to CO_2 ... give [illegible] lbs. C to CO ... " [illegible] lbs. vol. matter " [illegible] 4.33 lbs. O required; from air obtained [illegible] × 4.40 N	1.892 .33 .0252 4.43	25.637 2.83 .588 59.8	8183 ..... 592	28.80 3.20 .66 67.34	88.18 9.80 2.02 .....
Total	6.0774	88.855	8775	100.00	100.00
Calorific power in 1 lb. of coal	.....	.....	13535	.....	.....
Efficiency of producer, 64.8%					

TABLE No. 47.—EFFICIENCY OF AIR-BITUMINOUS PRODUCER.

Daviess County, Indiana, bituminous coal (see Table No. 19, Indiana No. 5).
Composition: 42% carbon, 48% volatile matter.
Calculated calorific value = 14200 British Thermal Units per pound.

	Pounds of gas.	Cubic feet of gas.	B. T. U.	Volumetric analysis of gas.	Volumetric analysis of gas. nitrogen subtracted.
1. *Good Practice.*					
2% C burned to CO_2.					
.4116 lbs. C to CO..give	.959	12.995	4148	22.00	52.95
.0084 lbs. C to CO_2. "	.03075	.26445	.....	.45	1.08
.48 lbs. vol. matter.. "	.48	11.1936	7925	19.10	45.97
.4284 × 1.33 = .56977 lbs. O required; from air obtained .56977 × 4.46 N	2.54126	34.307	.....	58.45	.....
Total.....	4.01101	58.76005	12073	100.00	100.00
Calorific power in 1 lb. of coal	.....	.....	14200	.....	.....
Efficiency of producer, 85.02%					
2. *Medium Practice.*					
6.66% C burned to CO_2.					
.392 lbs. C to CO...give	.91337	12.377	3950	20.50	50.50
.028 lbs. C to CO_2.. "	.10248	.88	.....	1.48	3.65
.48 lbs. vol. matter. "	.48	11.1936	7925	18.60	45.85
.448 × 1.33 = .59584 lbs. O required; from air obtained .59584 × 4.46 N	2.65744	35.8754	.....	59.42	.....
Total.....	4.15329	60.3260	11875	100.00	100.00
Calorific power in 1 lb. of coal	.....	.....	14200	.....	.....
Efficiency of producer, 83.62%					
3. *Poor Practice.*					
10% C burned to CO_2.					
.378 lbs. C to CO...give	.88074	11.936	3810	19.40	48.44
.042 lbs. C to CO_2.. "	.15372	1.32	.....	2.15	5.36
.48 lbs. vol. matter. "	.48	11.1936	7925	18.50	46.20
.462 × 1.33 = .6145 lbs. O required; from air obtained .6145 × 4.46 N	2.73	36 855	.....	60.00	.....
Total.....	4.24446	61.3046	11735	100.00	100.00
Calorific power in 1 lb. of coal	.....	.....	14200	.....	.....
Efficiency of producer, 82 64%					

[illegible] that the air-anthracite producer efficiency will vary from [illegible] per cent to [illegible] per cent, depending upon the quantity of carbon dioxide. These figures, however, do not take into consideration [illegible] radiation, unconsumed fuel and sensible heat [illegible] by the gas made. The figures, therefore, are theoretical entirely, and must be corrected for these inevitable losses.

There are many opportunities of employing fuels containing a greater or a smaller quantity of volatile hydrocarbon constituents, and [illegible] marked advantage results from the distilling action that takes place. To exemplify the effect of volatile fuel constituents, Table No. 17, Efficiency of Air-Bituminous Producer — may be [illegible]. The same is calculated and arranged in a manner precisely [illegible] to Table No. 16, excepting that bituminous coal from Brazil County, Indiana, is assumed as fuel supplied to the producer. The same variation in unreduced carbon dioxide, namely, from 5 to 10 per cent, is assumed in order to compare the producer outputs with that furnished by anthracite. The decrease in carbon monoxide and the marked increase in volatile matter are striking features here exhibited. As hydrogen develops the highest calorific power of any known substance, the air-bituminous producer affords a much richer gas, and therefore the increase in unreduced carbon dioxide produces much less effect upon producer efficiency with bituminous fuel. From 82 to 93 per cent efficiency may be reasonably realized, thus demonstrating the superiority of bituminous coal for gasification.

For convenience in determining either the calorific power of producer gas of known composition, or in ascertaining producer efficiency, Table No. 18, Efficiency of Air-Producer — may be employed.

The top line of the table, numbered from right to left, from [illegible] to 90, is devoted to the carbon percentage per pound of coal, while the respective diagonals, extending from the top line of the table downward to the left hand side, indicate the percentage of volatile matter. From the lower line, at the point of [illegible], diagonals extending upward to the left-hand side of the table are devoted to per cent of carbon burned to carbon dioxide. To determine the producer efficiency or thermal units per pound of [illegible] used, select upon the upper line of the table the percentage of carbon in one pound of coal. Follow a vertical line downward to the intersection with the diagonals devoted to the per

cent of carbon burned to carbon dioxide, indicating the amount of carbon dioxide that occurs. From this intersection follow a horizontal line to an intersection with the diagonal indicating the appropriate content of volatile matter. From this intersection follow a vertical line downward to the base line of the table, finding thereon the number of B. T. U. per pound of coal to be obtained by burning the gas manufactured. In the example given in the table, a pound of coal containing 60 per cent carbon and 25 per cent volatile matter is assumed, 5 per cent of the carbon being unreduced from carbon dioxide. Assuming coal to have an average calorific power of 14,500 B. T. U., the second or lower scale on the bottom line of the table expresses the efficiency of the producer.

With the early form of Siemens' producer much difficulty was experienced in obtaining good results, as the fire tended to burn into holes, allowing free oxygen and unreduced carbon dioxide to pass through the producer. This effect was particularly noticeable along the sides of the furnace where the fuel came into contact with the fire-brick walls. When air leakage occurred, a much higher temperature was produced by the complete oxidation of the carbon, with the consequent formation of bad clinkers and the slagging and cutting away of the fire-brick walls. To obviate this trouble it was necessary to constantly stir the fire in order to break up such holes, thus causing a loss of unconsumed carbon through the grate bars into the ashes and admitting cold air into the center of the combustion zone. Many improvements have been introduced in gas producers that have tended to render them more efficient, and more easily operated with the expenditure of a less degree of skill; but as the examination of such improvements belongs more properly to the sections upon apparatus rather than to those devoted to a discussion of the principles of the fuel, this portion of the subject will be relegated to future paragraphs.

In the Siemens gas producer it has been shown that about 30.6 per cent of the calorific power of the carbon is expended in the chemical transformation of the carbon to carbon monoxide, and that as the gases pass away from the producer at a very high temperature, parting only with such a portion of the sensible heat evolved by the combustion of the fuel as can be absorbed by the superincumbent bed of fuel above the combustion zone, a large

proportion of this heat is lost unless the gas can be immediately used.

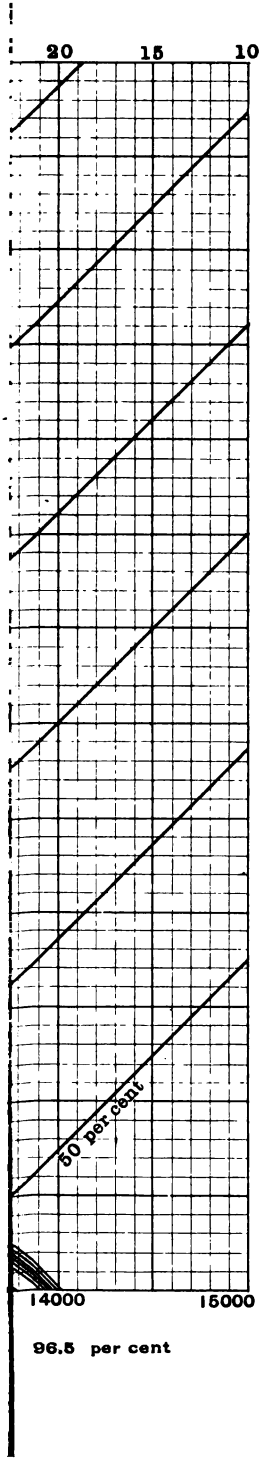
In an effort to produce a cheap gas of greater calorific power than that afforded by the Siemens producer, what is now known as the water gas process was invented. If over a bed of incandescent carbon, steam, or water in the state of a vapor, be passed, chemical decomposition occurs, which may be represented by the following equation:

$$C + O H_2 = C O + 2 H \qquad (26)$$

the incandescent carbon, tearing the water apart, absorbing the oxygen to form carbon monoxide and setting the hydrogen free. The gas resulting from this decomposition consists of carbon monoxide and pure hydrogen, relieved entirely of the diluting presence of inert nitrogen or equally noxious carbon dioxide. Furthermore, as hydrogen has the highest calorific power of any known substance, the gas resulting from this process has a great heating power. To oxidize one pound of carbon to carbon monoxide requires 1.33 pounds of oxygen, as water is composed of $\frac{8}{9}$ by weight oxygen and $\frac{1}{9}$ hydrogen, 1.5 pounds of water must be decomposed to supply the necessary oxygen to combine with one pound of carbon, therefore the resulting gas will consist of 2.33 pounds of carbon monoxide and .17 pounds hydrogen, or a total of 2.5 pounds of gas.

When carbon monoxide is burnt to carbon dioxide 10,050 B. T. U. are evolved, while the .17 pounds of hydrogen yield on combustion 10,540 B. T. U., and the gas resulting from the gasification of one pound of carbon, by the water gas process will give a fuel capable of yielding 20,590 B. T. U. per pound of carbon consumed, or 42 per cent more energy than that of the original coal itself. Seemingly this process would afford a solution of the famous, though ancient, problem of eating one's cake and having it too, and it is upon such a partial consideration of the facts involved that would-be promoters of the unscrupulous or ignorant order base their glittering assertions designed to entrap the unwary capitalist.

Unfortunately, the reaction outlined can only take place at quite a high temperature, not less than 1,000° Fahr., and for every pound of hydrogen set free from the watery vapor, 64,000 B. T. U. must be supplied as the energy necessary to effect the desired composition. If, therefore, to a bed of coal already



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heated to incandescence, steam be supplied, the reaction above will commence and continue until the heat absorbed by the dissociation of the water extracts so much of the heat of the glowing coal as to reduce the temperature and chill the mass below to that point at which decomposition cannot take place. As a prerequisite, the coal must have been heated to incandescence, either by the combustion of a portion of *itself*, or by obtaining heat from some external source. Thus there is *no real gain* of energy, for the hydrogen is obtained entirely at the expense of heat put into or derived from the coal bed. As a matter of convenience, however, this method has great advantages, for with its aid a gas can be made of very high calorific power, as the dissociation of water absorbs so large an amount of heat that it is impracticable to maintain the fuel at such a degree of incandescence as will enable this chemical transformation to proceed continuously. To make water gas it is usually customary to use a producer very similar to that of the Siemens type, excepting that it is considerably higher in proportion to its diameter. The cylindrical chamber for the reception of the fuel is quite like to that of the Siemens apparatus, excepting that the fuel occupies nearly the entire volume of the combustion chamber, giving a deeper bed of carbon. After the fire is started an air blast is turned on and the fuel furiously fanned until the coal is raised to a bright incandescence. This is termed "blowing the producer." As soon as the mass is thoroughly incandescent, the air blast is shut off and steam admitted to the fuel. Owing to the heat absorbed by the dissociation of the steam, the temperature of the producer rapidly falls and in a few minutes is so thoroughly chilled that no further reaction ensues. As soon as the chilling has proceeded so far as to allow a sensible amount of steam to pass through the fire, the steam blast is shut off, the air blast turned on, and the fuel is again blown to incandescence. Thus, the process of manufacture proceeds by a series of remittent cycles in which the producer is first heated to incandescence by blowing and then cooled by the admission and decomposition of the steam.

It is obvious that to afford a continuous supply of gas it is necessary to arrange two or more producers to work alternatively or else to store the gas in a receptacle of sufficient size so that during the intervals of blowing there will be no cessation of gas supply. The manufacture of water gas as thus outlined, though

producing a gas of very high calorific power, proves to be quite inefficient. During the period of "blow" a large proportion of the coal charge is burned in order to raise the fuel to incandescence. As the fuel bed is necessarily very deep, combustion is incomplete, much carbon monoxide being made, and the gas escaping from the producer at a high temperature. It is possible to greatly improve efficiency by supplying the producer with a set of regenerative chambers built of fire brick checker work, similar to those always used with the Siemens regenerative furnace. In Fig. 4 a cross section of the producer thus arranged may be found.

Examining the illustration it is apparent that this apparatus is laterally symmetrical about the line *H H*, the producer occupying the center. The fuel chamber is shown at *A* with the valve for charging the fuel at *V*. On either side and at the top and bottom of the combustion chamber *A* are pipes *M M*, and *E E*, for the inlet and exit of the air and gas. These pipes open from two chambers, *B B*, and *B' B'* placed on either side of the producer that are filled with fire brick checker work. The apparatus is operated as follows: After the producer is filled with fuel and the combustion initiated, the valve *G'* is shut, *F* is opened, *G* is opened and *F* is closed. Air supplied through the pipe *R'* passes through the chambers *B' B'*, thence through the fuel in the producer into the checker work on the right-hand side, and finds exit through the right-hand pipe, *R*. As the exit gases are intensely heated, the checker work on the right-hand side absorbs the sensible heat otherwise wasted. When the fuel is sufficiently hot the valves *G'*, *F'*, *G* and *F* are each reversed. Steam is forced in through the pipe *R*, passing through the highly heated checker work *B B*, thence through incandescent fuel and outward through the pipes *R'* and *O'*, and heat the checker work *B' B'*, parting with a portion of the sensible heat to this latter checker work, thus completing one cycle of the water gas process. The office performed by the checker work is that of absorbing the sensible heat of the exit gas during one part of the cycle in order to yield this heat to the inlet gases during the other half of the same cycle.

Notwithstanding the improvement in economy, effected by the regenerator, as applied to the water gas producer, this method, while giving a most valuable fuel for certain metallurgical opera-

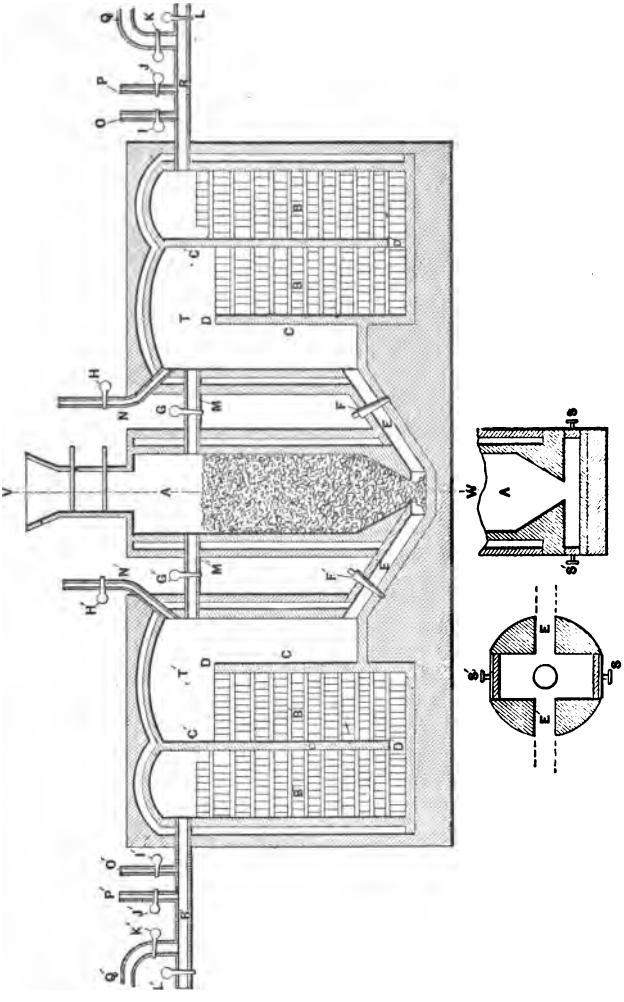


FIG. 4.—REGENERATIVE PRODUCER.

tion and when carburetted lending itself admirably to illuminating gas manufacture, could not compete with solid fuel. By a combination of both the water gas and the air producer, a happy mean has been obtained and a solution of the problem of gasification attained that is now all but universally adopted. The Siemens process labors under the disadvantage of evolving 4,050 B. T. U. that are chiefly expended in raising the temperature of the gas made, and of supplying a gas containing only 40 per cent of combustible matter. If in some way a large portion of the heat evolved could be stored up in the gas evolved, thus enriching it, economy in both directions could be secured. This is effected by the addition of a steam jet to the Siemens producer, whereby a small proportion of watery vapor is added, and both reactions are combined in the same furnace, securing some of the advantages of each process, and eliminating many of the faults common to each. The Siemens producer runs too hot, owing to the heat evolved in combustion to carbon monoxide. The water gas process chills rapidly, owing to the enormous amount of heat required to dissociate the water. Plainly if just a sufficient amount of water be added to the Siemens producer to absorb in dissociation the heat set free by combustion to carbon monoxide, the producer will run cool, the surplus heat will be stored in the hydrogen set free by the decomposition of the steam, and the heating power of the gas will be increased in just this proportion. Further, if the proper quantity of air is constantly admitted, there is no chilling of the furnace, the process is a continuous one, and no losses are introduced by the wasteful period of "blow." The success of this combination depends on the relative adjustment of fuel, air and steam, so that the producer may be run as cold as is permissible to secure the desired reactions. All the oxygen of the air supplied should be absorbed and converted to carbon monoxide, all the steam decomposed, and the smallest amount possible of free oxygen and unreduced carbon dioxide pass through the apparatus.

The next step is the determination of the relative proportion of air and steam. Neglecting for the present the ash in the fuel, loss through grate bars, and radiation from the furnace, assume that the lowest temperature at which dissociation can take place is 1,000° Fahr., and that all the heat evolved in the combustion of carbon to carbon monoxide is absorbed in either dissociation

of the water, or used in raising the elements entering into the reaction to the dissociation point.

One pound of carbon requires for combustion 1.33 pounds of oxygen, to be obtained partly from air and partly from steam. Let X be that *fraction* of the oxygen obtained from the steam, thus X will be a coefficient or multiplier, then $1.33\,X$ will be the number of pounds of oxygen derived from the steam to oxidize 1 pound of carbon, and $1.33\,(1 - X)$ will be the weight of oxygen obtained from the air. As water consists of 8 pounds of oxygen to 1 pound of hydrogen, the decomposition of such a quantity of water as will yield $1.33\,X$ pounds of oxygen will set free $\frac{1.33\,X}{8}$ pounds of hydrogen. To decompose a pound of water absorbs 62,000 B. T. U., hence to set free $\frac{1.33\,X}{8}$ pounds of hydrogen will need

$$\frac{1.33\,X}{8} \times 62{,}000 = 10{,}340\,X \text{ B. T. U.} \qquad (27)$$

As this heat is to be obtained from the combustion to carbon monoxide of 1 pound of carbon, this quantity of heat must be equal to that evolved by the partial combustion of the carbon, hence

$$10{,}340\,X = 4450 \qquad (28)$$

$$X = .435 \text{ and} \qquad (29)$$

$1.33 \times .435 = .58$ pounds of oxygen to be obtained from steam. In order that the producer shall be self-acting all of the heat derived from the combustion to carbon monoxide cannot be supposed to be stored in the released hydrogen, but a part must be expended in making the steam, and in heating the fuel and air. Allowing 1,000 B. T. U. as the latent heat of steam and .480 as the specific heat, the number of B. T. U. expended

In steam making is $1.5\,X$ 1,000	$= 1{,}500\,X.$
To heat the steam 1,000° Fahr. $1.5\,X\,(1{,}000 - 212)\,.480$	$= 1{,}082\,X.$
" " " air to " " $5.78\,(1 - X)\,(1{,}000 - 62)\,.24$	$= 1{,}300\,(1 - X).$
" " " fuel to " " $.2\,(1{,}000 - 62)$	$= 187.5.$

Thus $10{,}340\,X = 4{,}450 - (1{,}487.5 + 1{,}282\,X)$

$$\text{and } X = .25 \qquad (30)$$

Theoretically, then, one-fourth of the oxygen should be supplied by steam, and therefore sufficient steam must be supplied to

yield .33 of a pound of oxygen and sufficient air to give 1 pound of oxygen. To supply the preceding quantities, .415 pounds of water and 5.73 pounds of air is required. In practice it is never possible to quite realize these figures, although under skillful treatment about one-fourth of the gasification may be accomplished by steam, leaving the other three-fourths to be accomplished by the air supplied.

To fully appreciate the water gas process as thus outlined, Tables Nos. 49 and 50 have been prepared, giving an analysis of the producer reactions in a manner similar to the development of the processes carried on in the air-anthracite and air-bituminous producers outlined in Tables Nos. 46 and 47.

In the analyses of Tables Nos. 49 and 50, the same coals, namely, Beaver Meadow anthracite and Davies County bituminous coal, are hypothecated, and the quantities of unreduced carbon dioxide vary from 2 to 10 per cent. As it is impossible to determine or to assume the amount of energy wasted or fuel consumed during the period of "blow," it is therefore impractical to calculate the producer efficiency with reference to the original value of the coal, consequently these tables are chiefly valuable as indicating the calorific power of the gas produced and the reactions taking place in the producer. It should be here carefully noted that the calorific power of the output in reference to the kind of fuel is precisely the opposite from that given by the air producer. With the steam processes, greater calorific power is obtained with anthracite coal, while the reverse is true of the air producer. As the enrichment of the gas depends upon the hydrogen content, it is easy to understand this reversal, for the purer the coal the greater will be the quantity of steam decomposed and the larger the amount of hydrogen in the resulting gas.

To compare the process of the mixed producer with the practice of the air and steam producer, Tables Nos. 51 and 52 may be referred to, that are elaborated on precisely a similar method to that employed to outline the reactions of the preceding processes. The same coal is assumed, and the reactions of the mixed producer worked out for both anthracite and bituminous coal, and the same percentages of unreduced dioxide predicated. For the anthracite producer the efficiency is shown to vary from 83 to 87 per cent, while for the bituminous producer it is possible to realize from 91 to 93 per cent. With the mixed producer a

reversal of efficiency occurs, as would naturally be expected, in favor of the hydrogeneous fuel.

To still more clearly portray the action of the three forms of producer, Table No. 53 is a graphic exhibition of the reactions that may take place. On the left-hand side of the table, calorific power in B. T. U. is indicated. The line *A B* represents the heating power of carbon. When burned in the air-producer to carbon monoxide, 4,450 B. T. U. are sacrificed, and the point *C* indicates the calorific power of the resulting gas. If varying quantities of carbon dioxide are permitted to escape unreduced, the calorific power of the resulting gas falls, being represented by the line *C D*, showing that when all of the coal is burned to carbon dioxide, a gas of zero calorific power results. The percentages of unreduced carbon dioxide will be found upon the lower horizontal scale. Such is a representation of the working of an air-producer.

Turning to the water gas process, if a unit weight of carbon be burned completely to carbon dioxide and all the oxygen for the combustion be assumed to be derived from the dissociation of steam, a certain amount of hydrogen will be set free and the resulting gas will consist of hydrogen and carbon dioxide. Under these circumstances the heating value of the carbon in the resulting gas is zero and the point *A* falls to zero; but the hydrogen derived from the dissociation of the steam will have sufficient heating power to yield 35,166 B. T. U. per pound of carbon consumed, indicated by the point *F* on the diagram. If a portion of the carbon is burned to carbon monoxide instead of to carbon dioxide, less oxygen is needed, less steam is dissociated, and the calorific power yielded by the hydrogen set free by the decomposition of the steam falls, as represented by the line *F E*, while at the same time heat may be recovered by the combustion to carbon dioxide of such a portion of the carbon as is not completely burned, represented by the line *C D*. The calorific power of the gas will evidently be the sum of the heating power of the hydrogen plus that of the carbon monoxide, and is represented by the vector sum of the ordinates of the lines *C D* and *E F*, given in the line *I J*.

In a mixed producer, the heating value of the coal *A* drops to point *C* by combustion to carbon monoxide and is augumented by the hydrogen set free by the dissociation of the steam.

TABLE No. 49.—EFFICIENCY OF STEAM - ANTHRACITE PRODUCER.

Beaver Meadow anthracite (See Table No. 19, Pennsylvania No. 7 *.)
Composition: 90.2 per cent carbon, 2.52 per cent volatile matter.
Calculated calorific power = 13535 British Thermal Units per pound.

	Pounds of gas.	Cubic feet of gas.	B. T. U.	Volumetric analysis of gas.
1. *Good Practice.*				
2% C burned to CO_2.				
.884 lbs. C to CO.....give	2.06	27.913	8909	48.00
.018 lbs. C to CO_2..... "	.06588	.5686	.....	.98
.0252 lbs. vol. matter..... "	.0252	.588	592	1.02
.920 × 1.33 = 1.2236 lbs. O required; from steam obtained $\frac{1.2236}{8}$ H.....	.15295	29.06	9483	50.00
Total.....	2.30403	58.1296	18984	100.00
2. *Medium Practice.*				
6.66% C burned to CO_2.				
.842 lbs. C to CO.....give	1.962	26.585	8485	44.70
.06 lbs. C to CO_2..... "	.22	1.89	.....	3.18
.0252 lbs. vol. matter..... "	.0252	.588	592	.98
.962 × 1.33 = 1.2795 lbs. O required; from steam obtained $\frac{1.2795}{8}$ H.....	.16	30.5	9920	51.14
Total.....	2.3672	59.563	18997	100.00
3. *Poor Practice.*				
10% C burned to CO_2.				
.812 lbs. C to CO.....give	1.892	25.637	8183	42.50
.09 lbs. C to CO_2..... "	.33	2.83	.....	4.75
.0252 lbs. vol. matter..... "	.0252	.588	592	.97
.992 × 1.33 = 1.32 lbs. O required; from steam obtained $\frac{1.32}{8}$ H.....	.165	31.5	10230	51.78
Total.....	2.4122	60.555	19005	100 00

* Page 216, ELECTRICAL ENGINEERING, March, 1896.

TABLE No. 50.—EFFICIENCY OF STEAM-BITUMINOUS COAL PRODUCER.

Daviess County, Indiana, bituminous coal (See Table No. 19, Indiana No. 5*.)

Composition: 42 per cent carbon, 48 per cent volatile matter.

Calculated calorific value = 14200 British Thermal Units per pound.

	Pounds of gas.	Cubic feet of gas.	B. T. U.	Volumetric analysis of gas.
1. *Good Practice.*				
2% C burned to CO_2.				
.4116 lbs. C to CO.....give	.959	12.995	4148	34.20
.0084 lbs. C to CO_2..... "	.03075	.26445	.....	.69
.48 lbs. vol. matter..... "	.48	11.1936	7925	29.40
.4284 × 1.33 = .56977 lbs. O required; from steam obtained $\frac{.56977}{8}$ H.....	.07122	13.5318	4416	35.71
Total.....	1.54097	37.98485	16489	100.00
2. *Medium Practice.*				
6.66% C burned to CO_2.				
.392 lbs. C to CO.....give	.91337	12.377	3950	32.10
.028 lbs. C to CO_2..... "	.10248	.88	.....	2.28
.48 lbs. vol. matter..... "	.48	11.1936	7925	29.00
.448 × 1.33 = .59584 lbs. O required; from steam obtained $\frac{.59584}{8}$ H.....	.07448	14.1512	4618	36.62
Total.....	1.57033	38.6018	16493	100.00
3. *Poor Practice.*				
10% C burned to CO_2.				
.378 lbs. C to CO.....give	.88074	11.936	3810	30.70
.042 lbs. C to CO_2..... "	.15372	1.32	.....	3.41
.48 lbs. vol. matter..... "	.48	11.1936	7925	28.50
.462 × 1.33 = .6145 lbs. O required; from steam obtained $\frac{.6145}{8}$ H.....	.07681	14.5939	4762	37.39
Total.....	1.59127	39.0435	16497	100.00

*Page 211, ELECTRICAL ENGINEERING, March, 1896.

TABLE No. 51.—EFFICIENCY OF MIXED PRODUCER.

Beaver Meadow anthracite (see Table No. 19, Pennsylvania No. 7).
Composition : 90.2 % carbon, 2.52 % volatile matter.
Calculated calorific power = 13535 British Thermal Units per pound.

	Pounds of gas.	Cubic feet of gas.	B. T. U.	Volumetric analysis of gas.	Volumetric analysis of gas, nitrogen subtracted.
1. *Good Practice.*					
2% C to CO_2.					
.884 lbs. C to CO...give	2.06	27.913	8909	35.80	76.80
.018 lbs. C to CO_2... "	.06588	.5686	.....	.73	1.57
.0252 lbs. vol. matter "	.0252	.588	592	.76	1.63
.920 × 1.33 = 1.2256 lbs. O required;					
.3064 lbs. O from steam give H	.0383	7.277	2375	9.35	20.00
.9192 lbs. O from air give N	3.0747	41.5089	.....	53.36	.....
Total.....	5.26408	77.8555	11876	100.00	100.00
Calorific power in 1 lb. of coal	.....	.....	13535	.....	.....
Efficiency of producer, 87.74%					
2. *Medium Practice.*					
6.66% C burned to CO.					
.842 lbs. C to CO...give	1.962	26.585	8485	33.30	72.50
.06 lbs. C to CO_2... "	.22	1.89	.....	2.36	5.15
.0252 lbs. vol. matter "	.0252	.588	592	.74	1.63
.962 × 1.33 = 1.2795 lbs. O required;					
.32 lbs. O from steam give H	.04	7.6	2480	9.50	20.72
.96 lbs. O from air give N	3.218	43.44	.....	54.10	.....
Total.....	5.4652	80.103	11557	100.00	100.00
Calorific power in 1 lb. of coal	.....	.....	13535	.....	.....
Efficiency of producer, 85.38%					
3. *Poor Practice.*					
10% C burned to CO_2.					
.812 lbs. C to CO...give	1.892	25.637	8183	31.40	69.50
.09 lbs. C to CO_2... "	.33	2.83	.....	3.47	7.66
.0252 lbs. vol. matter "	.0252	.588	592	.72	1.59
.992 × 1.33 = 1.32 lbs. O required;					
.33 lbs. O from steam give H	.0412	7.83	2554	9.61	21.25
.99 lbs. O from air give N	3.318	44.89	.....	54.80	.....
Total.....	5.6046	81.773	11329	100.00	100.00
Calorific power in 1 lb. of coal	.....	.....	13535	.....	.....
Efficiency of producer, 83.70%					

TABLE No. 52.—EFFICIENCY OF MIXED PRODUCER.

Daviess County, Indiana, bituminous coal (see Table No. 19, page 211, Indiana No. 5).

Composition: 42 % carbon, 48 % volatile matter.

Calculated calorific power = 14200 British Thermal Units per pound.

	Pounds of gas.	Cubic feet of gas.	B. T. U.	Volumetric analysis of gas.	Volumetric analysis of gas, nitrogen subtracted.
1. *Good Practice.*					
2% C burned to CO_2.					
.4116 lbs. C to CO..give	.959	12.995	4148	27.50	46.45
.0084 lbs. C to CO_2. "	.03075	.26445	.....	.55	.93
.48 lbs. vol. matter.. "	.48	11.1936	7925	23.75	40.05
.4284 × 1.33 = .56977 lbs. O required;					
.14244 lbs. O from steam give H.....	.0178	3.382	1104	7.25	12.57
.42733 lbs. O from air give N.....	1.42943	19.2973	.....	40.95	.....
Total.....	2.91968	47.13235	13177	100.00	100.00
Calorific power in 1 lb. of coal.....	.....	.....	14200	.....	.....
Efficiency of producer, 92.80%					
2. *Medium Practice.*					
6.66% C burned to CO_2.					
.392 lbs. C to CO...give	.91337	12.377	3950	25.70	44.10
.028 lbs. C to CO_2.. "	.10248	.88	.....	1.85	3.18
.48 lbs. vol. matter. "	.48	11.1936	7925	23.30	40.10
.448 × 1.33 = .59584 lbs. O required;					
.14896 lbs. O from steam give H.....	.01862	3.5371	1154	7.35	12.62
.44688 lbs. O from air give N.....	1.495	20.1826	.....	41.80	.....
Total.....	3.00947	48.1703	13029	100.00	100.00
Calorific power in 1 lb. of coal.....	.....	.....	14200	.....	.....
Efficiency of producer, 91.75%					
3. *Poor Practice.*					
10% C burned to CO_2.					
.378 lbs. C to CO ..give	.88074	11.936	3810	24.40	42.40
.042 lbs. C to CO_2.. "	.15372	1.32	.....	2.77	4.80
.48 lbs. vol. matter.. "	.48	11.1936	7925	23.00	39.90
.462 × 1.33 = .6145 lbs. O required;					
.1562 lbs. O from steam give H.....	.0192	3.6482	1190	7.46	12.90
.4609 lbs. O from air give N.....	1.54171	20.813	.....	42.37	.....
Total.....	3.07537	48.9108	12925	100.00	100.00
Calorific power in 1 lb. of coal.....	.....	.....	14200	.....	.....
Efficiency of producer, 91.02%					

TABLE No. [illegible]. — EFFICIENCY OF MIXED PRODUCER.

Beaver Meadow anthracite (see Table No. [illegible], Pennsylvania No. [illegible]).
Composition: [illegible] % carbon, [illegible] % volatile matter.
Calculated calorific power = [illegible] British Thermal Units per pound.

	Pounds of gas.	Cubic feet of gas.	B. T. U.	Volumetric analysis of gas.	Volumetric analysis of gas, nitrogen subtracted.
1. *Good Practice.* [illegible] % C burned to C O. [illegible] lbs. C to C O ... give	[illegible]	[illegible]	[illegible]	35.50	76.80
[illegible] lbs. C to C [illegible] "	[illegible]	[illegible]	[illegible]	.73	1.57
[illegible] lbs. vol. matter "	.0252	[illegible]	592	.76	1.63
[illegible] × [illegible] = [illegible] lbs. O required; [illegible] lbs. O from steam give H	[illegible]	[illegible]	[illegible]	9.35	20.00
[illegible] lbs. O from air give N	[illegible]	[illegible]	[illegible]	53.36	[illegible]
Total	[illegible]	[illegible]	[illegible]	100.00	100.00
Calorific power in 1 lb. of coal	[illegible]	[illegible]	13535	[illegible]	[illegible]
Efficiency of producer, [illegible] %					
2. *Medium Practice.* [illegible] % C burned to C O. .962 lbs. C to C O ... give	1.962	26.555	8485	33.30	72.50
[illegible] lbs. C to C O_2 ... "	.22	1.89	[illegible]	2.36	5.15
.0252 lbs. vol. matter "	.0252	.588	592	.74	1.63
.962 × 1.33 = 1.279 lbs. O required; .32 lbs. O from steam give H	.04	7.6	2480	9.50	20.72
.96 lbs. O from air give N	3.218	43.44	[illegible]	54.10	[illegible]
Total	5.4652	80.103	11557	100.00	100.00
Calorific power in 1 lb. of coal	[illegible]	[illegible]	13535	[illegible]	[illegible]
Efficiency of producer, 85.38%					
3. *Poor Practice.* 10% C burned to C O_2. .812 lbs. C to C O ... give	1.892	25.637	8183	31.40	69.50
.09 lbs. C to C O_2 ... "	.33	2.83	[illegible]	3.47	7.66
.0252 lbs. vol. matter "	.0252	.588	592	.72	1.59
.992 × 1.33 = 1.32 lbs. O required; .33 lbs. O from steam give H	.0412	7.83	2554	9.61	21.25
.99 lbs. O from air give N	3.318	44.89	[illegible]	54.80	[illegible]
Total	5.6046	81.773	11329	100.00	100.00
Calorific power in 1 lb. of coal	[illegible]	[illegible]	13535	[illegible]	[illegible]
Efficiency of producer, 83.70%					

TABLE No. 52.— EFFICIENCY OF MIXED PRO

Daviess County, Indiana, bituminous coal (see Table [illegible] Indiana No. 5).

Composition : 42 % carbon, 48 % volatile matter.

Calculated calorific power = 14200 British Thermal U[illegible]

	Pounds of gas.	Cubic feet of gas.	B. T. U.	Vol[illegible] ana[illegible] of [illegible]
1. *Good Practice.*				
2 % C burned to CO_2.				
.4116 lbs. C to CO..give	.959	12.995	4148	27 [illegible]
.0084 lbs. C to CO_2. "	.03075	.26445	.....	[illegible]
.48 lbs. vol. matter.. "	.48	11.1936	7925	2 [illegible]
.4284 × 1.33 = .56977 lbs. O required ;				
.14244 lbs. O from steam give H.....	.0178	3.382	1104	7.2[illegible]
.42733 lbs. O from air give N.....	1.42943	19.2973	.....	4[illegible]
Total.....	2.91968	47.13255	13177	10[illegible]
Calorific power in 1 lb. of coal			14200	...
Efficiency of producer, 92.80%				
2. *Medium Practice.*				
6.66% C burned to CO_2.				
.392 lbs. C to CO...give	.91337	12.[illegible]	[illegible]	
.028 lbs. C to CO_2.. "	.10248	[illegible]		
.48 lbs. vol. matter . "	.48	11.1936	[illegible]	
.448 × 1.33 = .59584 lbs. O required ;				
.14896 lbs. O from steam give H.....	.01862	[illegible]	[illegible]	
.44688 lbs. O from air give N.....	1.495	[illegible]		
Total.....	3.00947	4[illegible]		
Calorific power in 1 lb. of coal			[illegible]	
Efficiency of producer, 91.75%				
3. *Poor Practice.*				
10% C burned to CO_2.				
.378 lbs. C to CO ..give	.88074	11.[illegible]	[illegible]	
.042 lbs. C to CO_2.. "	.15372	[illegible]	[illegible]	
.48 lbs. vol. matter.. "	.48	11.1936	[illegible]	
.462 × 1.33 = .6145 lbs. O required ;				
.1562 lbs. O from steam give H.....	.0194	[illegible]	[illegible]	
.4608 lbs. O from air give N.....				

TABLE No. 53.—COMPARISON BETWEEN RESULTS OBTAINED FROM AIR, STEAM AND MIXED PRODUCERS.

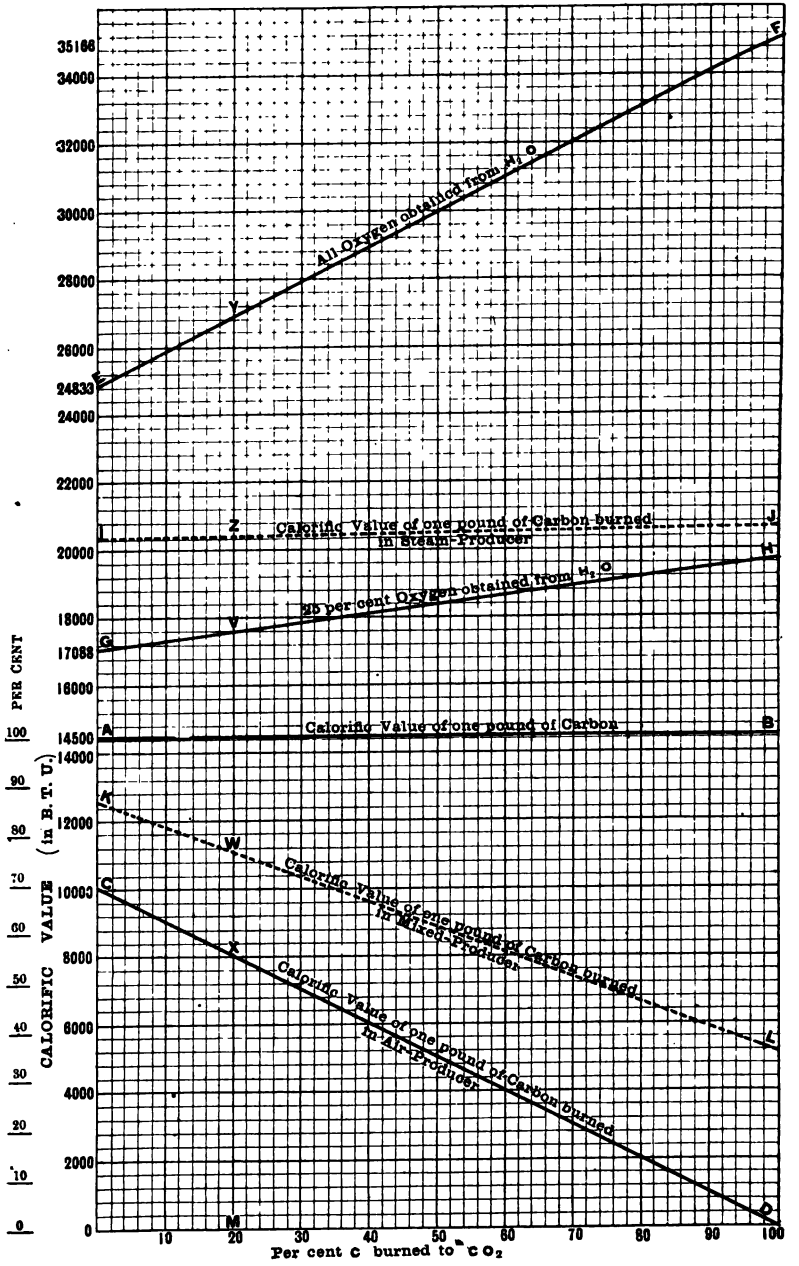
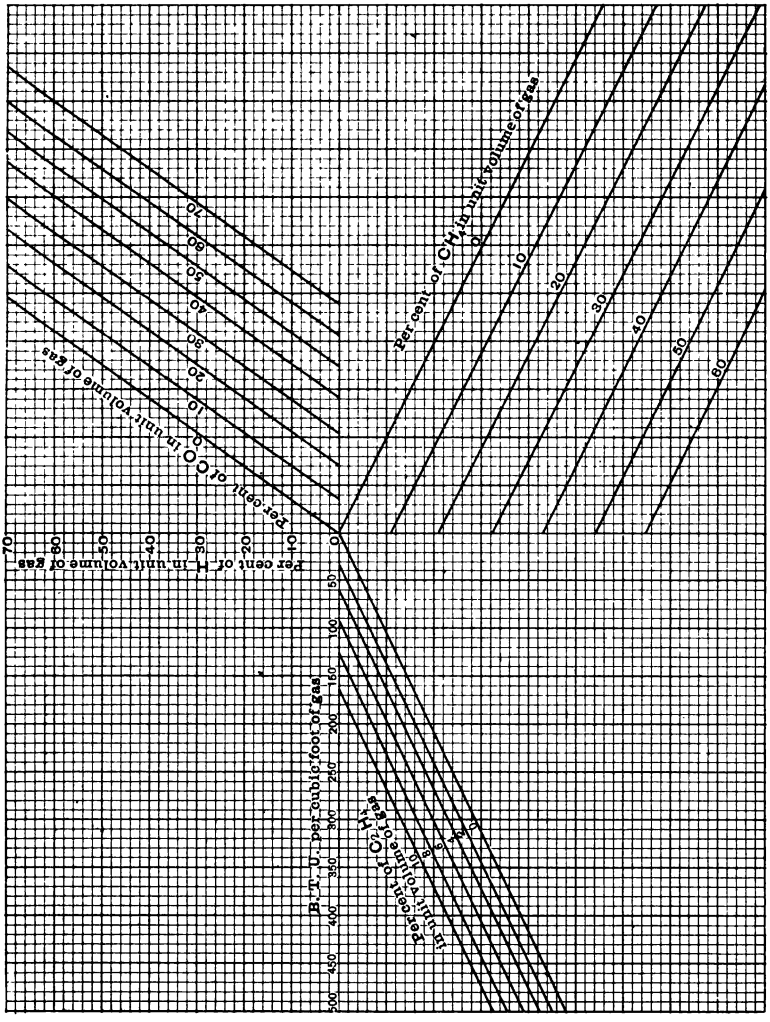


TABLE No. 55.—DETERMINATION OF CALORIFIC VALUE OF GAS BY VOLUME.



Allowing one-fourth of the oxygen to be derived from the steam, the calorific value o C is increased by A G, thus giving a total calorific power of o K on the assumption that no carbon dioxide is allowed to escape unreduced. For varying percentages of unreduced carbon dioxide, the calorific value of the resulting gas will be indicated by the vector sum of the ordinates of the lines C D and G H, giving the line K L. From this table the action of every form of producer may be readily and immediately obtained. The analyses of the preceding tables demonstrate conclusively the value of the mixed producer process for gasification, and when it is considered that upward of from 85 to 90 per cent of the fuel may be utilized, and that by means of the producer the initial cost of fuel may be halved or quartered, it becomes quite surprising to consider how little advance has been practically realized in the employment of gas plants for central station operation. Not only can fuel bills be materially decreased but capital invested in central station machinery, so far as the boiler plant is concerned, may be decreased, and the labor account and maintenance charges lightened by the use of gaseous combustible. As the various forms of producer processes thus described are commonly encountered, the composition, both volumetric and gravimetric, of the fuels afforded by the various methods will be found by consulting Table No. 54 — Composition of Various Producer Gases.

Knowing the composition of any producer gas, either by volume or by weight, Tables Nos. 55 and 56 are given to facilitate calculation of calorific power. From the analytical data, the hydrogen percentage in Table No. 55 will be found occupying the upper center line, while the diagonals assigned to carbon monoxide, methane and ethylene will be found successively occupying the three quadrants of the table proceeding clockwise from the hydrogen line from right to left. To determine calorific power, select upon the hydrogen line the given percentage and follow a horizontal to the right to the intersection with the carbon monoxide diagonal bearing the known percentage of this gas. From this intersection follow a vertical downward to the intersection with the methane diagonal, thence a horizontal to the left to the intersection with the ethylene diagonal, thence a vertical upward to the horizontal line carrying the B. T. U. scale, finding here the thermal units per cubic foot of gas.

TABLE No. 54.—COMPOSITION OF VARIOUS PRODUCER GASES.

DESCRIPTION OF GAS.	ANALYSIS BY VOLUME							ANALYSIS BY WEIGHT.						
	H	CH_4	CO	CO_2	N	O	C_nH_{n+2}	H	CH_4	CO	CO_2	N	O	C_nH_{n+2}
Water gas, uncarburetted	52.88	2.16	36.80	3.47	4.69	.....	.....	7.22	2.39	70.89	10.47	9.03	.....	.....
" " carburetted	30.00	24.00	29.00	0.30	2.50	0.20	14.00	3.28	21.23	44.66	0.72	3.84	0.34	25.93
Dawson gas	18.73	1.16	17.55	6.57	48.98	0.03	0.15	1.68	0.83	22.20	13.20	61.86	0.04	0.19
" "	24.36	.....	21.00	6.07	50.48	0.23	4.00	1.98	.....	24.00	11.00	58.12	0.39	4.60
Lencauchez gas	20.00	4.00	21.00	5.00	49.50	0.50	.....	1.59	2.55	31.40	8.72	54.10	1.64	.....
Lowe gas	30.00	.....	28.00	34.00	8.00	.....	.....	2.33	.....	30.50	58.40	8.77	.....	.....
Rew gas	42.50	15.60	25.50	0.10	3.00	0.30	13.00	5.63	16.4	47.2	0.29	5.55	0.63	24.3
Strong gas	53.00	.....	35.00	4.00	8.00	.....	.....	7.2	.....	66.00	11.80	15.00	.....	.....
Wilkinson gas	32.00	24.00	25.00	4.00	.....	.....	15.00	3.68	22.00	40.12	10.2	.....	.....	.....
Producer Gas.							C_2H_4							C_2H_4
Anthracite gas, without steam	.....	1.37	27.79	3.70	67.14	.....	.....	.....	0.77	27.26	5.71	66.26	.....	.....
Bituminous gas, without steam	.....	11.88	23.67	4.01	60.44	.....	.....	.....	6.95	24.2	6.45	62.4	.....	.....
Anthracite gas, steam blast, good	9.4	1.6	33.4	2.0	53.6	.....	.....	0.75	1.0	36.41	3.42	58.43	.....	.....
" " " " normal	9.68	1.49	30.24	4.02	54.57	.....	.....	0.74	0.92	32.5	6.8	59.04	.....	.....
" " " " poor	9.8	1.4	27.3	5.8	55.7	.....	.....	0.75	0.85	29.3	9.7	59.4	.....	.....
Bituminous gas, steam blast, good	8.3	13.2	27.8	2.7	48.0	.....	.....	0.67	8.5	31.6	4.78	54.5	.....	.....
" " " " normal	8.6	12.6	24.0	5.3	49.5	.....	.....	0.68	8.7	26.8	9.25	55.2	.....	.....
" " " " poor	8.9	12.0	20.4	7.7	51.0	.....	.....	0.7	7.5	22.4	13.4	56.0	.....	.....
Siemens producer, anthracite	12.0	1.2	27.0	2.5	56.2	0.3	.....	0.96	0.77	30.44	4.43	63.02	0.38	.....
" " bituminous	12.0	2.5	27.0	2.5	56.2	0.3	.04	0.96	1.59	30.2	4.4	62.43	0.38	0.04
" " Cambria Iron Works	12.0	.....	28.0	4.0	56.0	.....	.....	0.95	.....	31.0	6.95	61.1	.....	.....
" " Midvale	6.0	3.0	23.6	1.5	65.9	.....	.....	0.45	1.82	25.	2.5	70.23	.....	.....
Philipps producer, Hoops & Townsend, fan blast	.....	1.4	27.3	3.9	67.4	.....	.....	.....	0.78	26.8	6.02	66.4	.....	.....
" " " " " steam blast	15.3	1.9	16.0	7.5	59.3	.....	.....	1.22	1.21	18.0	13.2	66.37	.....	.....
Taylor's producer No. 4 (coal: 80.41% C, 6.88% vol. matter, 4.2% H_2O, 8.51% ash, 0.74% S)	4.51	1.79	25.38	4.02	64.04	0.26	.....	0.33	1.05	26.08	6.50	65.81	0.23	.....
Wilson producer	11.55	1.45	26.89	4.00	56.11	.....	.....	0.91	0.93	29.6	6.9	61.66	.....	.....
Producer gas from coal containing 57.98% C, 36.22 vol. matter, 3.78% ash, 1.26% H_2O, 0.7% S	9.2	3.1	25.3	3.4	58.2	.....	0.8	0.72	1.93	27.65	5.83	63.00	.....	0.87

[illegible] DETERMINATION OF CALORIFIC VALUE OF GAS BY WEIGHT.

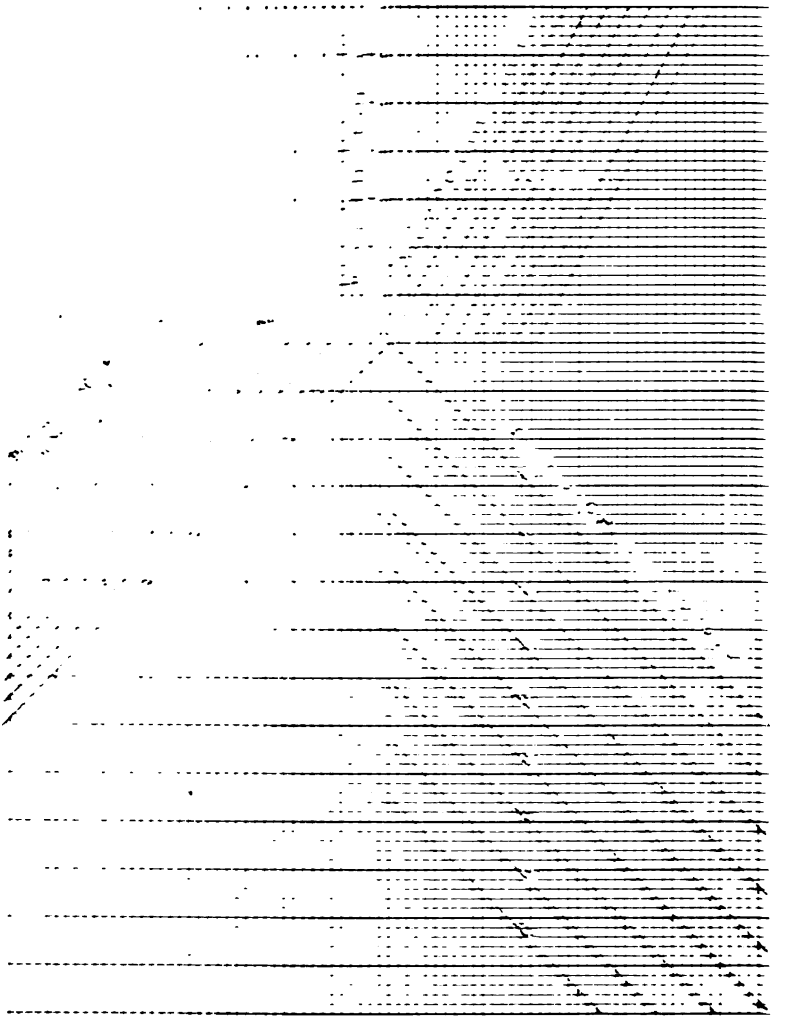


TABLE No. 57.—FOR CALCULATION OF VOLUME OF AIR REQUIRED FOR COMPLETE COMBUSTION OF ONE UNIT VOLUME OF GAS.

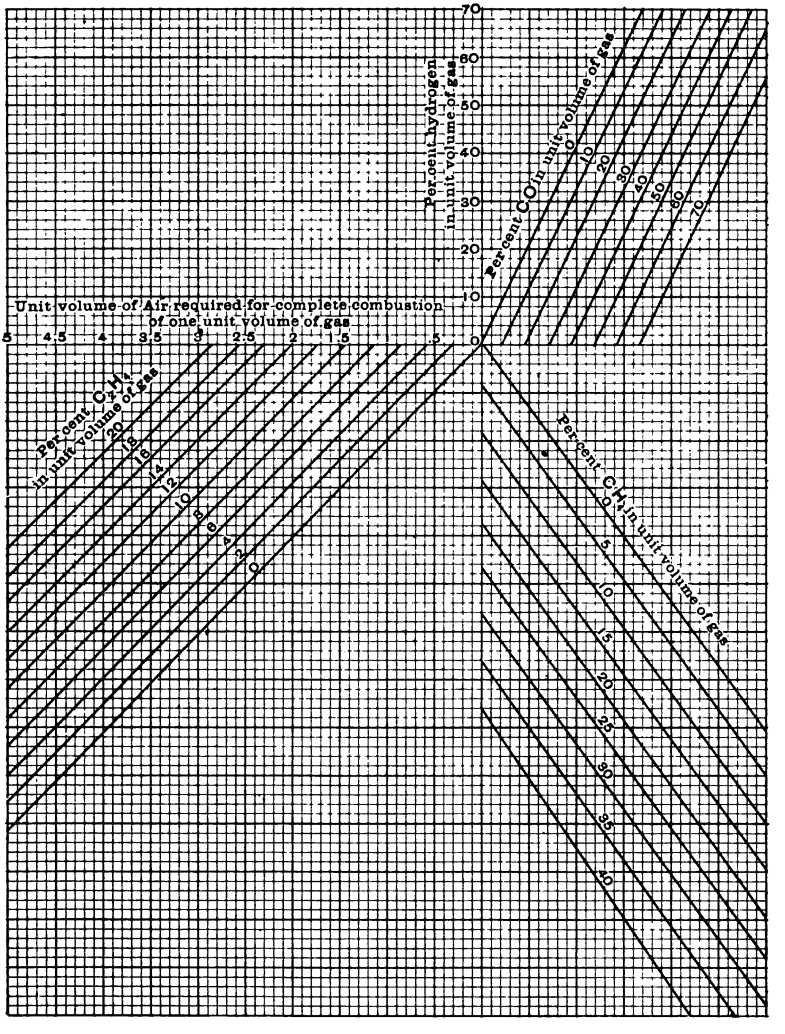


Table No. 56 is precisely similar to Table No. 55, excepting that it is calculated for calorific value by weight. The construction and use of the table is as outlined for Table No. 55.

As an aid to proportionating stacks, gas ports and other furnace passages, the determination of the amount of air for the complete combustion of any gas is valuable. Table No. 57 is presented for this purpose, and may be used when the volumetric composition of the fuel gas is known. Upon the right center line of the table the percentage of hydrogen will be found. Succeeding are the quantities of carbon monoxide, methane and ethylene, occupying diagonals in the successive quadrants of the table, clockwise from right to left. The volume of air is ascertained by following the line from the hydrogen percentage horizontally to an intersection with the carbon monoxide diagonal, thence vertically downward to an intersection with the methane diagonal, thence horizontally to the left to an intersection with the ethylene diagonal and thence vertically upward to the scale headed Unit Volume of Air Required for the Complete Combustion of the Gas.

The three fundamental processes that have thus been considered, namely: That of the distillation of coal, the Siemens air-producer, and the water gas process, form the basis of a large number of different methods that have been attempted for the purpose of supplying gas for calorific and illuminating purposes, and having considered at length the reactions that occur in the fundamental operations, a brief consideration of the various supplementary processes is in order. The earliest attempts to obtain gas for other purposes than that of illumination were made by Bishof in 1839. The process was essentially that of the air-producer, peat fuel being burned in a brick chamber, to which a limited supply of air was admitted. The apparatus, however, was so crude that the resulting gases were too poor to be successful. In 1840, Abelmann exploited a similar experiment with the addition of an air blast, by means of which the quality and quantity of gas was much improved. In 1841, Messrs. Thompson and Laurent designed the first thoroughly successful gas producer. Compressed air, furnished by a blower, was supplied, and the blast aided by the introduction of a steam jet which, in reality, served to make the process that of a mixed water gas and air-producer. The fuel used was charcoal, wood, peat, coke and anthracite. In

1852, Messrs. Kirkham, working on similar lines as Thompson and Laurent, produced a good quality of gas by direct combustion of coal in a furnace instead of by distillation. The process used was essentially that of the modern water gas process, as the fuel was alternately blown to incandescence and treated with superheated steam. In 1861, Pascal attempted to improve upon the intermittent water gas process by designing an iron retort which should be filled with coal and heated in an external furnace, the idea being that the external fire would supply sufficient heat so that the decomposition of the steam admitted to the retort should be made continuous. The process, however, was not fully successful. In 1871, Tessie-du-Motay improved upon the previous methods of water gas manufacture to such an extent that his apparatus is at present used to a greater extent than any other in large gas plants. The Motay's improvement consists in making the generator of sufficient height to attain the most economical results. For the purpose of illumination the water gas was enriched by sprinkling a small quantity of oil upon the top of the incandescent fuel. The glowing carbon and heated gases decomposed the oil spray into fixed gases which were taken up by the outgoing gases and furnished the necessary supply of carbon to secure the desired illuminating characteristics. In 1874, two investigators, Messrs. Strong and Lowe, improved upon the water gas process by applying to the generator fire brick chambers of checker work, by means of which the famous Siemens regenerative principle was adapted to water gas manufacture, thus resulting in the saving of a large amount of heat that was otherwise rejected during the process of blowing the producer. For purposes of illumination, both the Lowe and Strong gas was enriched by sprinkling heavy hydrocarbon oil into the producer during the emission of the steam. In the Wilson process an improvement is introduced that aims at a more equitable distribution of the steam and air blast into the center of the furnace. Instead of emitting the steam and air into the ash pit, a conical pipe is arranged to extend entirely through the ash bed of the converter, the pipe being so designed as to admit of 20 per cent perhaps of air to 1 per cent of steam, conveying the same directly to the center of the fuel bed. In 1891, Lencauchez introduced several minor advantages into the producer process, by improving the proportions of the furnaces used and regulating

more carefully the admixture of steam and air. The Lencauchez process is an intermittent air-steam process, enriched with oil for the purpose of illumination. Mr. J. Emerson Dowson is perhaps entitled to the credit of having first perfected the continuous steam-blown producer. Though the gas obtained is poorer than pure water gas, it is a great improvement over the air-blown producer and can be rapidly and continuously generated. With the proper admixture of air, it is an excellent fuel for internal combustion engines, and when mixed with oil, forms a good illuminating gas. It has, further, the advantage of being excellently adapted to illumination by means of incandescent burners. The Mansfield process is an attempt to manufacture illuminating gas by the decomposition of refuse oils and fats. A furnace, very similar in shape to the water gas producer, is arranged, containing an interior cylindrical retort. By means of an external fire, this retort is kept at a high degree of incandescence. To the interior of the retort refuse fats and oils of any description are slowly fed. As the drops of oleaginous matter fall upon the incandescent surface of the iron they are decomposed into fixed hydrocarbon gases which may be washed and scrubbed in a manner similar to that used for illuminating gas. The process is only applicable to the manufacture of gas for lighting, excepting in such cases as permit of a large supply of refuse oils at a very cheap rate. Mr. James Keith devised essentially a similar apparatus for the manufacture of gas from petroleum refuse. The Pintsch oil gas system has obtained a wide currency for the illumination of railway trains. The method is quite similar to that of Keith and Mansfield, and consists of the decomposition of crude petroleum in highly heated retorts. The gas is subsequently compressed into cylinders and supplied to the burners under the initial pressure from the cylinder. As a fuel, however, the Pintsch process gas would be too expensive to enter into competition with the solid forms.

δ. WOOD.

Although wood, both geographically and historically, has attained the widest range as a fuel, it is not of important economic consideration compared with coal, natural gas and oil. Wood, as a combustible, may be divided into two classes — the hard and relatively compact woods, such as oak, beech, elm and ash, and the light or soft woods, pine, birch and poplar. When wood is first felled it contains on an average about 45 per cent of moisture, detracting to an enormous extent from its value as a combustible, as a large proportion of the calorific power is expended in evaporating the contained water. Even when carefully dried, the quantity of moisture is a notable amount, rarely falling below from 18 to 20 per cent. When freshly cut the amount of moisture in the various kinds of fuel wood are indicated in Table No. 58.

TABLE No. 58.— SHOWING THE PERCENTAGE OF WATER IN DIFFERENT KINDS OF FRESH-CUT WOOD.

Name of Wood.	Percentage of Water.	Name of Wood.	Percentage of Water.
Hornbeam	18.6	Pine	39.7
Willow	26.0	Reed beech	39.7
Sycamore	27.0	Alder	41.6
Mountain ash	28.3	Aspen	43.7
Ash	28.7	Elm	44.5
Birch	30.8	Red fir	45.2
Wild service tree	32.3	Lime tree	47.1
Oak	34.7	Italian poplar	48.2
Pedicle oak	35.4	Larch	48.6
White fir	37.1	White poplar	50.6
Horse-chestnut	38.2	Black poplar	51.8

By kiln drying, it is feasible to remarkedly reduce the percentage of water, but artificial dessication is only valuable when the wood may be preserved free from contact with the air, for the reason that after being thoroughly dried, wood is hygroscopic, and if exposed to the atmosphere will reabsorb sufficient moisture to bring the average content to from 15 to 20 per cent.

The calorific power of fuel woods may be determined from an ultimate analysis, a number of experiments to ascertain this for the most common woods being given in Table No. 59.

TABLE No. 59.- COMPOSITION OF WOODS.

Woods	Composition.				
	Carbon	Hydrogen	Oxygen.	Nitrogen.	Ash.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Beech	49.56	5.01	42.60	0.91	1.60
Oak	49.61	5.02	41.16	1.29	1.97
Birch	50.29	5.29	41.62	1.15	0.81
Poplar	49.57	5.21	41.60	0.60	1.86
Willow	49.66	5.96	39.56	0.96	3.37

From these and other researches, there appears to be a remarkable identity in the composition of all woods which come under the fuel category. Analyses from different parts of the same tree also indicate great uniformity in composition. Average results, in Table No. 60, show the following composition to be reliable within probable experimental errors, and variations due to climatic differences.

TABLE No. 60.- AVERAGE COMPOSITION OF WOOD.

Carbon	50	per cent.
Hydrogen	6	" "
Oxygen	41	" "
Nitrogen	1	" "
Ash	2	" "

It here appears that there is not over 56 per cent of possible combustible matter, and that owing to the large quantity of oxygen, it is probable that the hydrogen is already in combination with it, thus reducing the calorific value to that of its contained carbon, amounting to 50 per cent.

The preceding analyses are based entirely upon laboratory experiments on wood that has been carefully dried. For ordinary firewood the available fuel constituents may be assumed in accordance with Table No. 61 — based on the results of a large number of experiments upon ordinary cord wood:

TABLE No. 61. AVERAGE COMPOSITION OF FIREWOODS.

Hygroscopic water	25	per cent.
Carbon	37.5	" "
Hydrogen	4.5	" "
Oxygen	30.75	" "
Nitrogen	0.75	" "
Ash	1.5	" "

From these data it appears that in commercial samples the contained carbon is decreased and that the hygroscopic water reduces the calorific power by the amount of the heat required for its evaporation.

Assuming dry firewood to have an average composition as per Table No. 61, the theoretical quantity of air necessary for combustion, the weight and volume of combustion products, as well as the calorific power and intensity, may be readily calculated, and are summarized in Table No. 62.

TABLE No. 62.—FUEL COEFFICIENTS FOR WOOD.

Calorific power	7,700 B. T. U.
Calorific intensity	3,700° Fahr.
Air required per pound of wood by weight	6.09 pounds.
Air required per pound of wood by volume	80 cubic feet.

COMBUSTION PRODUCTS PER POUND OF WOOD.

PRODUCTS.	By Weight.	By Volume at			
		62°	212°	400°	600°
Carbon dioxide	1.83	15.75	20.25	26.92	32.00
Steam	.54	11.40	14.66	18.76	22.15
Nitrogen	6.08	82.01	105.60	135.00	166.5

The volume occupied by wood becomes a serious consideration when the quantity used is large or the supply at all irregular. Even in a closely packed pile, the intersticial space is equivalent to from 40 to 50 per cent of the entire volume occupied. In Table No. 63 the relative weight and bulk of fuel woods is given.

TABLE No. 63.—RELATIVE WEIGHT AND BULK OF FIREWOOD.

NAME.	Weight of One Cubic Foot.	Bulk of One Ton.
Soft firewood	18.8 pounds.	119.1 cubic feet.
Hard firewood	23.4 "	95.7 " "
Oak, cut up	23.7 "	94.4 " "
Oak—small branches	19.8 "	113.1 " "
Fir	16.0 "	140.1 " "
Willow	18.0 "	124.7 " "
Pine	21.0 "	106.0 " "

The economic value of wood as a combustible in competition with other fuel supplies does not often enter into consideration, for the reason that the use of wood as a fuel is exclusively

[illegible] to [illegible] where the expense of obtaining other fuels is [illegible] in comparison with that of wood as to relieve the [illegible] consideration, or where wood forms a by-product of [illegible] branch of manufacture. Thus, in the lumber regions [illegible] wood is accordingly plenty and the distance from railways [illegible] commercially no possibility of obtaining coal or other mineral fuels, and wood forms the only available supply. In the case of large plants of wood-working machinery, the refuse of slabs or unmerchantable wood forms frequently a sufficient quantity to supply the fuel needed for manufacturing. In such cases, it is profitable to use wood as a fuel from the manufacturing standpoint, but under the more common circumstances of central station practice, the fuel value of wood is so small in comparison with either coal or gas as to be entirely excluded from a profit consideration. From the analytical results obtained in Table No. [illegible] it appears that over 50 per cent of the ordinary fuel wood is devoted to hygroscopic water and oxygen, both of which are deleterious constituents in so far as their influence upon fuel value is concerned. When wood is exposed to heat it is first dried and afterward carbonized. Under temperatures [illegible] the process is merely one of drying. [illegible] the gaseous elements are expelled [illegible] the volatile constituents [illegible] carbon usually known under the [illegible] black solid and brittle substance. [illegible] are not finally expelled [illegible]. Though the expulsion [illegible] diminishes the total calorific power [illegible] the process [illegible] the result [illegible] greater value [illegible] the losses thus [illegible] smaller grate [illegible] intensity than is [illegible] natural condition. [illegible] reduces the [illegible] non-conducting [illegible] fuel [illegible] has

become very widespread and its use is attended with a very marked economy over that of wood in its ordinary state.

The ancient, and even at the present more common, method for the manufacture of charcoal, consists in the piling of wood in heaps upon the ground, each stack or pile being covered with a mixture of powdered earth, charcoal and turf, so arranged as to admit to the pile a very limited amount of air. A few openings are left about the base, as well as a central orifice on the top of the pile. When the stack is lighted, it at first burns rapidly and as soon as the flame appears at the chimney top the supply of air is cut off by stopping the air holes with turf. Presently the mass becomes incandescent and is then entirely covered and allowed to cool. In this process the charcoal usually amounts to from 15 to 25 per cent of the total wood employed, and the time required for complete manufacture is from sixty to eighty hours.

By more carefully conducted processes of manufacture, the wood is placed in closed retorts and is distilled at a high temperature. By this means the yield of charcoal is greatly increased, and the volatile products from the wood may be condensed and saved, as they all have some commercial value. Wood alcohol, creosote and other hydrocarbons may thus be obtained. The yield of charcoal, together with its composition, depends largely upon the kind of wood used and the temperature at which carbonization takes place. Table No. 64 gives results of a series of experiments to determine the composition of the charcoal contained and the quantity of wood required for a given amount.

TABLE No. 64.—COMPOSITION OF CHARCOAL PRODUCED AT VARIOUS TEMPERATURES.

Temperature of Carbonization.		Composition of the Solid Product.				Carbon for a Given Wood.
		Carbon.	Hydrogen.	Oxygen, Nitrogen and Loss.	Ash.	
Degrees Cent.	Degrees Fahr.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
150	302	47.51	6.12	46.29	0.08	47.51
200	392	51.82	3.99	43.98	0.23	39.88
250	482	65.59	4.81	28.97	0.63	32.98
300	572	73.24	4.25	21.96	0.57	24.61
350	662	76.64	4.14	18.44	0.61	22.42
432	810	81.64	4.96	15.24	1.61	15.40
1023	1873	81.97	2.30	14.15	1.60	15.30

The effect of the kind of wood employed in the manufacture of charcoal is given in Table No. 65, from which it appears that cork, although the lightest of woods, gives the largest yield of charcoal, and poplar and chestnut the lowest. There does not, however, appear to be any definite relation between the density of the wood and the quantity of charcoal obtained.

TABLE No. 65.—YIELD OF CHARCOAL FROM VARIOUS WOODS, DRIED AT 150° CENT., OR 302° FAHR., AND CARBONIZED AT 300° CENT., OR 572° FAHR.

WOOD.	WEIGHT OF CHARCOAL.	WOOD.	WEIGHT OF CHARCOAL.
	Per cent.		Per cent.
Cork	62.30	Apple tree	34.69
Decayed willow	52.17	Elm	34.59
Wheat straw	46.09	Hornbeam	34.44
Oak	46.09	Alder	34.40
Yew	46.06	Birch	34.17
Beech	44.25	Plum tree	34.06
Pine	41.48	Maple	33.75
Poplar leaves	40.95	Willow	33.74
Poplar roots	40.90	Black elder	33.61
Wild pine	40.75	Ash	33.28
Larch	40.31	Pear tree	31.88
Chestnut tree	36.06	Lime tree	31.85
Cherry tree	35.53	Poplar stem	31.12
Aspen	34.87	Sweet chestnut tree	30.86

Charcoal exposed to the atmosphere shows itself to be markedly hygroscopic, absorbing from ten to twelve per cent of moisture within a few hours after it leaves the kiln. Its hygroscopic capacity, however, varies greatly with the kind of wood used in its formation. The relation between the absorption of moisture and the kind of wood is indicated in Table No. 66.

TABLE No. 66.—MOISTURE ABSORBED BY CHARCOAL DURING TWENTY-FOUR HOURS.

WOOD FROM WHICH THE CHARCOAL WAS MADE.	MOISTURE ABSORBED.	WOOD FROM WHICH THE CHARCOAL WAS MADE.	MOISTURE ABSORBED.
	Per cent.		Per cent.
White beech	0.8	Horse chestnut	6.06
Ash	4.06	Elm	6.60
Oak	4.28	Alder	7.93
Birch	4.40	Scotch fir	8.20
Larch	4.50	Willow	8.20
Maple	4.80	Italian poplar	8.50
Pine	5.14	Fir	8.90
Red beech	5.30	Black poplar	16.30

THE MANUFACTURE OF WIRE.*

BY FREDERIC A. C. PERRINE, D.Sc.

In order to determine the electrical and mechanical constants of wires drawn according to any one of the gauges we have described, reference must always be had to the terms in which the specific conductivity and specific weights of the materials are determined by various experimenters. The standard method being to express the specific conductivity in terms of the resistance between the opposite faces of a cubic centimeter, and the specific weight in terms of the specific gravity referred to water at 60° Fahr. as a standard. The resistance and weight of any wire being calculated from the contents of the wire considered as a cylinder.

In order to facilitate these calculations it is the custom of electrical engineers to employ as a unit of area the area of a circle one mil in diameter in place of the common unit, which is the area of a square one mil on a side; by this means the use of functions of the constant factor π is avoided in determining the relations between different wires of which the diameters are known. This unit of area we call the *circular mil;* it is not a simple mathematical convention, as has been often stated, but is a true area unit by means of which circles may be directly compared, it being the area of a circle of unit diameter to which the areas of all other circles are related as the squares of their diameters and the circumscribing square in the ratio of $\frac{4}{\pi}$ to one. Employing this unit we express the weight and resistance of any material in terms of its weight and resistance per mil foot, which is the weight and resistance of a cylindrical wire one mil in diameter and one foot in length. This standard weight and resistance may be found from the specific gravity and specific resistance of a wire by means of the following equations:

$$\text{Weight per mil foot} = \frac{\text{sp. gr.} \times 62.4}{144 \times 1{,}000{,}000} \times \frac{\pi}{4} =$$

$$.0000003403 4 \text{ sp. gr.}$$

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in which equation sp. gr. $\times$ 62.4 represents the weight in pounds of a cubic foot of the substance. Dividing this by 144 we obtain the weight of a square inch one foot long, which is multiplied by $\frac{\pi}{4}$ in order to obtain the weight of a cylinder one foot long and one inch in diameter, and this is finally divided by one million in order to express the diameter in mils.

In the same way we can obtain the resistance per mil foot from the specific resistance by first reducing the resistance between the face of a centimeter cube to the resistance of a square inch one foot long; multiplying by $\frac{4}{\pi}$ and dividing by one million, we obtain the resistance per mil foot, which is represented by the following equation:

$$\text{Resistance per mil foot in C. G. S. units} = \frac{\text{sp. r.} \times 30.48}{\frac{6.451}{1{,}000{,}000}} \times \frac{4}{\pi}$$

$$= \frac{\text{sp. r.} \times 30.48 \times 1{,}000{,}000}{6.451} \times \frac{4}{\pi} = 6{,}016{,}000 \text{ sp. r.}$$

From which equations, by proper substitution of the values for specific gravity and specific resistance, we may find the weight per mil foot or resistance per mil foot of any given material, and to determine the resistance and weight of any given wire the weight per mil foot would be multiplied by the product of the area in circular mils of the wire and its length in feet, since the weight of the wire increases as its volume, while for the resistance of a wire we should multiply the resistance per mil foot by the quotient obtained by dividing the length in feet by the area in circular mils, since the resistance of any wire is directly as its length and inversely as the area. If, as is generally the case, the resistance in ohms per mil foot is desired, the coefficient of the specific resistance in the above equation must be multiplied by 10^{-9} which gives

$$\text{Resistance per mil foot in ohms} = .006016 \text{ sp. r.}$$

When wires are used in the form of a strand, the weight of the strand is found to be closely three per cent greater than the weight of the constituent wires, which would also indicate that the resistance of the strand would be less than the resistance of the solid wire equivalent to the strand in area; but the change in resistance by twisting into a strand has never been accurately

determined experimentally, and without any experimental determination it is impossible to predict whether any strand will have conductivity appreciably varying from the equivalent solid wire, for the reason that while the weight of the strand is greater than the solid wire, the lengths of the constituent wires are also greater and if the current is supposed to follow along the individual wires in the direction of their axes the resistance would be increased in place of being diminished, and, by these two opposite possible suppositions, we are led to assume that the resistance of any strand will not greatly vary from the resistance of the equivalent solid wire.

In all circumstances, except where wire is used on pole lines out of doors, it has been found necessary to cover it with some material for the purpose of insulation, the character of the insulation being determined by the use to which the wire is to be put. Insulating coverings for wires may be divided into three distinct classes:

First. Those in which the covering is simply intended to separate wires by a space. Leakage being prevented either by the properties of the covering or by the insulating properties of the air contained within the space.

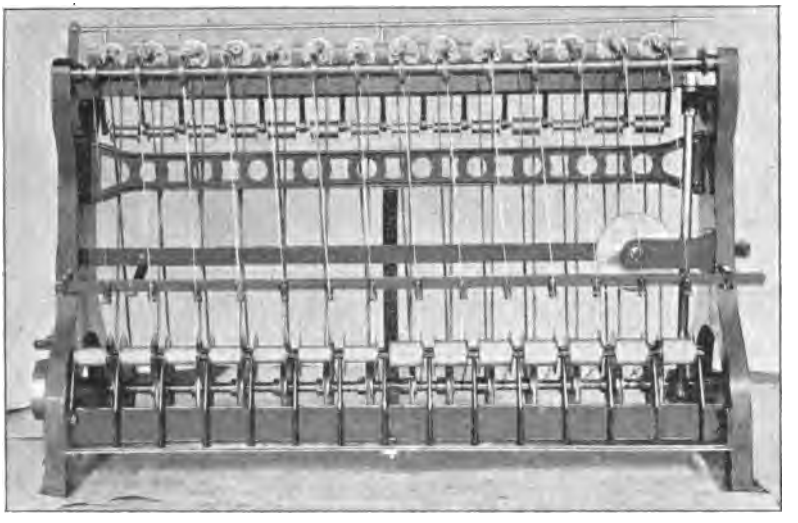
Second. Those in which the covering contains two essential elements, the first a material having high enough specific resistance to be considered an insulator, but weak mechanically; the second providing a mechanical support to keep the insulator in place and to enable the covering to resist pressure and abrasion.

Third. Those in which the covering is both high in specific resistance and is sufficiently strong to withstand mechanical abrasion or the action of the elements without auxiliary support.

Taking up these classes in order, we find that to the first class belongs a wire covering which is used for insulating in all electrical apparatus and is commonly called *magnet wire*. This covering consists of a winding of cotton, silk or other fiber thread, closely and uniformly applied to the wire in such a manner that the conductor will maintain its position relative to all other conductors without regard to mechanical strains applied to the conductor. The characteristics essential to a satisfactory magnet wire are: that the covering of itself when dry should be of high insulating power, that it should be applied to the wire in such a uniform manner that it will allow the wire to be placed in

a definite space, and that the covering should be sufficiently flexible to withstand a considerable amount of bending and abrasion. While other fibrous yarns might be used to obtain these qualities it is found that finely spun silk and cotton are the only materials available. The silk used is spun in such a manner that while being free from ends the twist of the thread shall be so loose as to allow the covering machines to spread it in an even and thin layer over the surface of the wire; the machine winding it upon the wire in a spiral of an exceedingly short pitch amounting in general to not more than $\frac{1}{100}$ of an inch per turn. Cotton is used in the form of spun yarn, which is distinguished from thread by its comparatively loose twist and by the fibers being all twisted in the same direction, the thread being composed of a number of yarns so twisted that it will maintain its cylindrical shape even when a considerable pressure is applied. The thickness of a single wind of silk when wound as we have described does not amount to more than 1 mil, while the smallest cotton yarn cannot be laid in a layer less than 2.25 mils in depth; greater thickness being obtained in the case of silk by more than a single winding laid on in such a direction that the yarn from the first covering crosses the yarn from the second covering on an opposite spiral.

With the cotton yarn we may increase the thickness of the insulation, as with silk, by increasing the number of layers; but also it has been found practicable to use yarns of greater diameter so that a single covering may be laid up to a thickness as great as 5 mils. Double winds are consequently used in cotton insulated wire, for the purpose of obtaining insulation which will be perfectly continuous, and for strength rather than for obtaining a great amount of thickness which, as we have explained, could be produced by increasing the size of the yarn, though it is in general found to be inadvisable to use a yarn giving a greater thickness than 5 mils, on account of the fact that the thicker yarns are soft in character and do not make wire which will withstand mechanical strains. The manufacture of this class of insulated wire requires the greatest care and the most perfect machinery, for the reason that the finished product must be as nearly as possible uniform in size, completely covered, and the surface so hard that the wire when placed will not change its position. In order to obtain these qualities the wire must be



WESTERN ELECTRIC INSULATING MACHINE.

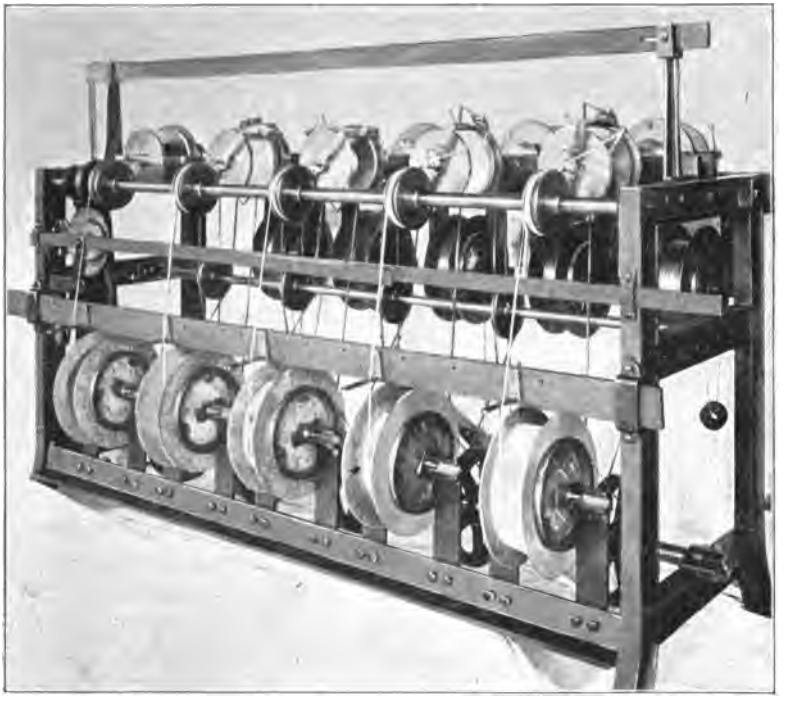
drawn through the machine at a definite rate in relation to the speed of the spools containing the yarn. Where more than one covering is applied at the same time, the drawing-out mechanism and the different sets of winding spools must all be so connected that there will not be any possibility of mechanical slip between the various parts. The yarn itself must be laid on under a considerable amount of tension which cannot be applied to a single strand of yarn, but only to many strands laid together, the tension being obtained partially by a spring retarding the spool from which the yarn is unwinding, and partially by the fact that the spools themselves revolve at a very high rate of speed as they wind the yarn onto the wire. All of these operations are performed so accurately in modern wire-winding machines that it is possible for manufacturers to guarantee absolute continuity of insulation, and that the variations in the diameter of insulated wire will not exceed 1 mil from the standard size.

In use, magnet wire, when perfectly made, forms a satisfactory insulation for most purposes without the application of any additional insulating material ; but where it is subject to considerable difference of potential between the different wires, and where it has to stand severe mechanical strains, it is more generally the custom

to saturate the insulation with shellac applied in solution, with asphaltum varnish, or to immerse the coil in an insulating oil. These additional precautions being mainly to prevent any absorption of moisture by the wire after it has been thoroughly dried than for increasing the insulating power of the dried cotton; the various materials used depending in value mainly upon their power to exclude moisture from the machinery under all conditions.

As being most closely allied to the magnet wire, we will next describe those coverings which rely for their insulation upon materials high in specific insulating property, but so weak mechanically that they demand support. In this class is included all wires insulated with the various waxes or asphaltums which have been from time to time used. Mechanical support for the insulator is offered by a yarn applied to the wire either by winding in the manner we have described for magnet wires, or by a process of braiding similar to the covering of a whip, or as the ribbons are braided upon a pole in the familiar maypole dance.

We should now carefully distinguish between the insulating properties of the yarn and of the waxes for which the yarn is designed solely as a support, the value of the covering depending upon the material with which the yarn has been saturated rather than upon any qualities inherent in the yarn itself, consequently those insulations are the best which make use of insulating materials which have at the same time the greatest specific insulating qualities and are able most perfectly to saturate the yarn. Since these coverings are designed for use in positions exposed to air, and often to a considerable amount of moisture from rain and atmospheric humidity, a perfect wire can only be obtained when a material is used which will not of itself absorb moisture or will allow moisture to be absorbed by the yarn which supports it. It has not been found possible to manufacture wire in this manner so that a continuous immersion in water will not destroy the insulation; for the reason that no material has been discovered which saturates a fibrous yarn so perfectly that it may not absorb moisture by continued immersion, and, indeed, many of the waxes employed will themselves absorb and retain a very considerable amount of moisture on continuous immersion, paraffin being particularly noticeable for this defect. In consequence, the common annunciator wire which is covered with a heavy cotton yarn saturated with paraffin wax is found to be most imperfectly insulated



WESTERN ELECTRIC INSULATING MACHINE.

and can only be used when installed in dry places, and even under such circumstances cannot be relied upon to maintain a high degree of insulation. The same defects belong to the cotton braided wire saturated with paraffin extensively used in telegraph practice and called *office* wire.

For the purpose of line construction, where a moderate degree of insulating property only is necessary, wires covered with a saturated braid have been extensively used, and their use has been successful where the wire was satisfactorily manufactured. The earliest of such wires is the common *underwriter's* wire, a covering composed of cotton braid saturated with white paint, the original idea being that the covering should not carry fire; and were it not for the fact that the covering used is incapable of withstanding the effects of the elements and that the materials employed can never completely saturate the yarn, this would form a satisfactory covering for the purpose of line insulation. The

saturating power of asphaltum, especially when melted with some of the softer waxes, such as ozocerite, is found to be very much greater than paint, while the material itself does not absorb any considerable amount of water on continuous exposure, though it is still defective in its power of completely saturating the yarn which is used for its mechanical protection.

Wires which are covered with asphaltum held in place by yarn are manufactured by passing the wire through a bath of molten wax, and immediately braiding upon the surface of the wire one or two independent braids; then after the wire has been again saturated in the molten wax it is passed through a machine provided with rapidly revolving steel plates, which rub the wax into the spaces between the yarns, and leave the surface brightly polished, thus furnishing an outer surface of continuous wax, from which all projections have been removed that would increase the adherence of sleet and snow. A more perfect insulation is made by covering the conductor, as we have already described, by a single braiding laid over the asphaltum, and then passing the wire so covered again through the insulating pots, at the same time applying two cotton braids, which are finished by external saturation and polishing. In this manner a greater amount of wax is retained by the yarn, and the saturation made more perfect, with the result that the finished covering depends for its insulation upon the insulating wax rather than upon the braid covering; the amount of wax retained in the covering furnishing the criterion by which we should judge the quality of any such wire. A greater apparent saturation can be obtained by the application of the wax when dissolved in a solvent than can be obtained by the processes we have already described by melting the wax alone by heat, but the subsequent evaporation of the solvent leaves a wax of porous character which is in a condition to absorb moisture more readily than when the insulation has been applied without a solvent.

No one of these wires can be tested by the application of any of the ordinary insulation tests, nor is it possible to specify that the wire should have a certain insulation resistance when it is manufactured, since, as we already described, the saturation of the yarn is never perfectly effected, and on immersion in water the covering will immediately begin the absorption of water until the insulation is finally broken down. The test for quality being

obtained by reference to the rate of fall of insulating power rather than by the insulation resistance either immediately after immersion or at any particular subsequent period. We see, therefore, that the quality of any such wire depends upon the character of the wax, the manner in which it has been applied, and the relative amounts of insulating material and yarn; that conductor being considered insulated in the best manner which has the largest amount of insulating material and the smallest amount of yarn. The question has often been discussed whether such wire should be purchased according to a price per foot, or according to a price per pound, as is the common practice throughout the country.

Should such wire be sold by the foot, the wire of the lowest price would be that in which the smallest amount of matter of all kinds were used as insulation, while the lowest price per pound is obtained by the use of the minimum amount of cotton and the maximum of wax or insulation, which is equivalent to an increase in the insulating property of the wire, since the cost of the insulating materials is less than either copper or yarn. We must also consider in this question of the prices for such wire that it is impossible to apply these insulating materials in an absolutely uniform manner unless the total amount of insulating material is made small in relation to the amount of yarn, which also leads us to consider that the best product will be obtained by purchasing on a standard of weight rather than upon a standard of length.

In the classes of insulation referred to as being of sufficient mechanical strength to withstand pressure and abrasion without auxiliary support, reference is made to those insulations which give the most complete electrical protection, since no auxiliary material must be introduced into the body of the insulator, and in consequence there are neither substances capable of becoming conductors by the absorption of water present in the body of the insulation, nor any discontinuity in the wire covering; but on the contrary, with these materials we may protect a wire by a continuous coat of a material both high in specific insulating power and impervious to any conducting liquid. In this class is included insulations composed of all forms of gutta-percha, rubber or other gums that have been used for covering wire.

Of the many natural gums and resins that we have at command for such purposes it is found that only two are capable of giving entire satisfaction; the first of these being gutta-percha, a gum

which is suitable for insulating wire without any preparation beyond that necessary for purifying it from all foreign matters.

The other gum referred to includes a great number of different natural gums, under the general name of rubber or caoutchouc, the different varieties being of essentially unlike characteristics, but having between themselves certain common properties and being of similar constituents.

Of the many varieties of gutta-percha which might be used wire insulation is only at its best when performed with the gum obtained from the Isondra gutta tree found in Sumatra and portions of the Island of Borneo and somewhat upon the Peninsula of Malacca, but principally marketed from Singapore. In certain parts of Venezuela a gum is found called Ballata, which seems to be closely allied to the true gutta-percha, but it is unfortunately obtained only in such small quantities that it has not been extensively used as an insulator. The gum from the Isondra gutta tree is obtained by the natives making incisions in the bark of the branches of the tree through which the sap exudes, and, drying in the sun, forms a waxy coating on the leaves and smaller twigs. This is then scraped off and rolled by hand into balls four or five pounds in weight, containing consequently many impurities from the inclosed twigs and pieces of bark, as well as occasionally a greater or less quantity of sand and gravel added for the purpose of adulteration. In the preparation of the gum these impurities must be removed with the greatest care in order to apply to the wire a perfectly continuous coating. This purification is performed by shredding the gutta-percha under a stream of warm water into fine pieces by passing it through two sets of cutting machines, which thoroughly separate the gum and enable the impurities to be removed by washing. After this has been satisfactorily performed the clean gum is masticated by a corrugated roll revolving within a confined space containing the gum immersed in warm water; finally the clean and masticated gum is dried in a press consisting of a heated cylinder, through a sieve at the end of which the gum is pressed by a piston, and lastly it is consolidated in a dryer containing a pair of corrugated rolls by means of which the gum is pressed firmly together and the last particle of moisture is removed. In this state the gutta-percha is ready for direct application to the wire or to be run out into a sheet through a set of calender rolls, if it is necessary to use the

gum in a uniform thin sheet. Wire covering, however, is rarely performed with sheet gutta-percha, since such a covering would necessarily involve a seam in the coating of insulation that might be imperfect and admit moisture through infinitesimal openings in the seam, but more generally the compressed gum is placed in a large cylinder jacketed with steam, out of which the gutta-percha is forced by either screw or hydraulic pressure and the wire covered with a continuous tube formed by a set of annular cores and dies, the core fitting snugly over the wire and the die determining the outside diameter of the gutta-percha coating.

Gutta-percha is principally employed in the construction of insulated core for submarine cables, the greatest care being taken to insure a perfectly continuous coating of insulator, and a thoroughly solidified mass of copper and gutta-percha covering, which will not absorb water through its end, even should the cable be broken at the bottom of the sea where the water pressure amounts to as much as six or eight thousand pounds per square inch.

For this purpose, the conductor is composed of a strand of seven small wires in order to obtain great flexibility and a certain amount of longitudinal elasticity, so that when strained the conductor and its covering will elongate and contract in unison. This strand is passed through a heated tank containing Chatterton's compound, made of:

Gutta-percha	3 parts
Resin	1 part
Stockholm tar	1 part

which effectually fills up the pores in the strand and cements the covering of gutta-percha to the wire. Over the strand so saturated three separate layers of pure gutta-percha are applied, as we have already described, these various layers being sometimes cemented together with a thin layer of Chatterton's compound, which until recently was the only approved method of manufacture; at the present time most of the makers consider that the resin in the compound is subject to crystallization, and that a better core is produced when the separate layers are laid without filling, firm contact between them being insured by cleansing and heating just before a new coat is applied. When the whole is complete, the core is tested for insulation by immersion in water, and finally strained in pressure and vacuum tanks for the purpose

of developing any mechanical imperfections that may have been previously formed in the covering.

A gutta-percha core so constructed is thoroughly insulated so long as the gum is protected from the oxidizing action of the air, as will be the case if it is immersed in water, but if left exposed to the air or sunlight it is found that the gum will oxidize to a brittle resin, and the valuable properties of high insulation and great flexibility will be lost. Before such a cable core can be immersed in the sea, it is necessary to provide sufficient mechanical protection and weight for it to withstand the rough handling incident to the laying of a long cable, and to insure its sinking promptly and lying quiet at the bottom of the sea. This protection is provided by coating the insulated core first with a bedding of tanned jute and finally by surrounding this juted core with a strand of galvanized iron wire, which must lastly be overwound with asphalted jute yarn in order to protect the galvanized iron wire from the action of the salts at the bed of the ocean, which occasionally have a serious corrosive action upon the armor.

THE TELEPHONE SITUATION.

BY FRED DE LAND.

The progress made by opposition telephone companies in establishing exchanges, toll lines, and toll stations, and the annoyance and expense that the Bell licensees have been subjected to by reason of this competition, is attracting the attention of investors in many localities where competition has not made its appearance. Naturally these investors wonder whether the parent company — the American Bell Telephone Company — has awakened to a clear understanding of the strength of the enemy in Pennsylvania, Ohio, Indiana, Michigan, Illinois and Iowa? And after a visit from the sleek telephone promoter, they wonder if the Bell officials realize that, once the interests of all these hundreds of competing companies are harmonized, the enemy's present strength will be so materially reinforced by the interlinking of all these exchanges and toll stations by toll lines radiating out from every town and every city, that within a year or two the country will be so covered by the opposition that the linking together will afford connecting toll lines from the Hudson to the Mississippi?

But the investor need not feel alarmed about the stability of the Bell interests, for the Bell officials keep posted on every move that is made by the opposition, as becometh men of wisdom and experience having their millions invested in a permanent and rapidly increasing form of public service. Nor do they fear that the progressive business man in any community will ever dream of patronizing the opposition toll lines so long as the direct and heavy copper circuits of the American company are maintained in their present perfect condition. For the successful business man realizes that it is *service*, and not *cost* that he must consider, when discussing important questions with customer or client. A "deal" that may have required months in the arrangement of certain details, and now requires but a few moments personal conversation to close, may be blasted by the annoyances that have ever been associated with imperfect and interrupted telephone service. To patronize a long-distance circuit made up of

a variety of interconnecting lines, some of steel wire, some of B B, some of E B B iron wire, with now and then a copper circuit, and supported on poles of tamarack, or black ash, or whatever timber the immediate locality may afford, or on insulators bracketed to trees, is just about as sensible as it would be to journey to New York over a succession of short and illy constructed railway lines, each under a separate management using a different system of switches, in place of making the trip over a heavily ballasted and efficiently managed trunk line.

These new toll lines and small competing exchanges are the best advertisers the Bell interests have ever had. They introduce the service among those who have had little or no experience with the telephone, and who heretofore have refrained from leasing an instrument on the ground that "we supposed we could not afford it." But personal experience has given an insight into the value and the economy inherent in the telephone, both as a time-saver and a business-bringer, and now only the best will satisfy these subscribers. And to this desire for the best may be traced the true reason for the closing of the many competing exchanges that have gone out of business, not by reason of litigation for infringements of patents, or for any pressure brought by the Bell interests, but simply to an inability to supply a quality of service satisfactory to the experienced user. And only from the regular user of the telephone can an assured and definite income be obtained by any exchange. The irregular user of the telephone is an expense and an annoyance. Not only is this proving true in the smaller towns, but also in cities like Grand Rapids, where some of the shrewd citizens, having the best interests of the city at heart, are questioning the permanency of their competing exchange that is probably the largest of its kind in the country. This exchange is reported to have fully 1,800 subscribers with 400 applicants on its books, and a prospective annual income of $50,000 on a reputed investment of $100,000. Could a more desirable condition of affairs be imagined? But, unfortunately, the Bell instrument forms a standard by which the quality of the service supplied in Grand Rapids is unconsciously being measured and often found wanting by the active, hustling business man holding no stock in either exchange, uninfluenced by the false sentiment aroused by the promoter, and only asking value received for his money.

If we look at the question from a local point of view, the telephone appears to be a natural monopoly, and the highest returns on the rental of an instrument can be secured where there is but one exchange. Thus, to encourage and support two exchanges is to add an additional burden on the business community, for the progressive business man must have telephonic communication with all subscribers to every exchange in his city, whether there be but the one or a dozen exchanges, each competing under circumstances that can only tend to destroy the efficiency of the service each supplies. And the merchant realizes that it is not competition that he desires so much as high-class service, and the better the service becomes, the less he objects to the cost. For there are houses that receive more business through the telephone door than ever enters through the doorway planned by the architect. Again, these merchants appreciate that when an intelligent public comprehends how intricate and varied are the problems facing the telephone question in every city, an earnest effort will be aroused to unitedly make the one exchange as complete and serviceable to the city as is possible. For the greater the number of subscribers connected to a telephone exchange the more valuable the service becomes to each subscriber, and the larger return each receives for the rental paid.

A NOTE ON CABLE-LAYING.

We have been laying some cables for three-wire feeders under rather unusual conditions. Woodward avenue is the central avenue of Detroit, and also the backbone (if the expression may be used) of the largest block of residence lighting in the district. This avenue is paved with asphalt on a concrete foundation, and the authorities object to its being disturbed except under very stringent regulations. As repaving this asphalt pavement is expensive and only possible in summer weather, most of the gas pipes and sewer connections and other excuses for excavating roadways are found in the alleys. Therefore we concluded that the avenue was a very desirable thoroughfare in which to place our unprotected cables, while the alleys, subject to a continual tearing up, were most undesirable. So we surveyed to our feeding points the straightest possible route affording practical immunity from disturbance and ordered a rubber insulated cable, lead covered and braided over the lead, which we laid without using a conduit or other shield from invading pickaxes.

The asphalt is 2½ inches thick, the concrete 6 to 8 inches. We have cut a trench 7 inches wide and 16 to 18 inches deep. In the bottom we lay 2½ inches of dry mortar — native cement, one part, and sharp sand, four parts, screened together — on which cushion we drop in the cables in lengths of 700 to 1,300 feet. We could have made one run of 2,200 feet if we had cared to handle such a weighty reel. You see the trench does not go deep enough to touch any obstacles. It is the ideal ditch, into which we only have to drop the cables, just like the nice, easy-looking pictures in the text-books, which no fellow ever was lucky enough to realize in practice — anyhow I never did till this time. My ditches have always been full of obstructions ("destructions" a former foreman of mine calls them), and I have always had to put cables not where I wanted, but where there happened to be room for them. On top of the cables we put three or four inches of wet mortar, mixed the same as the cushion, and the cushion absorbs enough moisture from the covering to make it set equally hard. Then comes the concrete and the asphalt, and since the last is down you cannot tell where the ditch was.

We have to guarantee the seams of the asphalt for three years as one of the conditions of being allowed to cut it; but we have gone over that question with the asphalt contractors and expect no trouble. We did figure on a conduit. If it had been a business district, or one likely to become so soon, the conduit would ' gone in.

ALEX DOW.

EDITORIAL OUTLOOK.

Who Sows the Seeds of Anarchy? Is it always the little group of men meeting in the back room of a suspected saloon and there discussing in fiery language the wrongs that the educated-heedless have ever pressed down on the ignorant, the poverty-stricken, the toiler? Or is it the group of prominent, well-fed, sleek-looking citizens who rent a great hall in the heart of the city, fill it to overflowing with their well-dressed associates, and there listen to the impassioned utterances on the evils that exist by reason of incompetent and inefficient officials? Unbridled utterances that tend to destroy all reverence for the office as well as for the official! that blind the unreasoning to the fact that the same power that placed can remove, that seated can unseat! that lead the thoughtless to forget that all evils are but temporary and not organic ailments of the body politic! that awaken within the oppressed and the depressed the longing that can never be fulfilled for a complete overturning of social as well as of political conditions! For these unfortunates have long realized that the very evils so loudly declaimed against would not have existed had speaker and hearer but discharged their duties as becometh the good citizens they so often and in such various fashion claim to be.

Is it any wonder that the toilers feel bitterly toward the great corporations when the knowledge of the evils, the bribery, the oppression charged against these employers of labor, is supplied by these would-be molders of public opinion and their sensational allies, the daily press? Who sows the seeds of anarchy? Is it the little sheet published in some back room, and in a language comprehended by only a fraction of the population? Or is it the great metropolitan daily, printing its thousands and sending broadcast statements that an hour's thoughtful honest investigation would have proved false and harmful? Partisan statements so venomous that they burn deep into the minds of the unreasoning who fail to perceive how false the premise, how fallacious the conclusion! statements possessing just enough of truth to engender the bitterness and arouse the antagonism of imagined

trespassed rights; that breed desire for revenge let the cost be what it may!

How rarely does the glib speaker or the partisan sheet explain that all corporations obtain their rights and privileges from the representatives of the people, and only after due publicity. If these representatives sign away the rights of the people, if the choice of the people prove incompetent or false, it is in the power of those who elected to displace. But having through action or inaction vested the management and control of public affairs in the hands of certain of their associates, why strive by false and libelous denunciation to destroy that reverence for law and for all lawful authority that the morally healthy endeavor to inculcate? Why promulgate statements that tend only to increase the bitterness that separates the so-called social classes? Why scatter broadcast thoughtless statements that tend to impoverish through the lessening of valuations?

Having been granted certain rights and privileges by the representatives of the people, it is but natural that a corporation should utilize these most advantageously, and branch out in every legitimate and profitable direction. For, save in a few specialized fields, the day of the small corporation has gone by. Then, as the output or the traffic of the corporation increases in magnitude, envious competition enters, and a fight begins that often lessens the selling price below the cost of production, a fight that usually results in severe financial loss to one or more of the combatants, and often ends in a pooling or an amalgamation of all the interests involved. For the directors, as becometh sensible men, vote for consolidation, concentration and a restoration of living prices, rather than have the stockholders lose all in a fruitless struggle. Then appeareth the sensational sheet reviling the directors, personally and collectively; and the demagogue findeth delight in declaiming against the action taken as "destructive to the rights and the best interests of the people," and "a species of legalized robbery."

Corporations rarely take any action that the terms of their charter will not warrant; and though action taken by virtue of charter rights may be in seeming variance to the rights of the people, yet the authority on which such action is based was

granted and legalized by the people through their chosen representatives. Moreover, the thoughtful comprehend that it is an exhibition of common sense on the part of the directors to accept a lesser rather than a greater loss, and that the small difference between the wrecking and the living price has gone into the pocket of the middleman rather than to the consumer. But once the interests are concentrated under good management it is the consumer that reaps the advantages and is directly benefited. For now the time, the attention and the ability heretofore devoted to waging a destructive warfare is utilized in improving the mechanical finish, the quality or the character of the product, or in supplying a higher class of public service comprising many new features. FRED DE LAND.

Telephone Exchanges. The competing telephone exchange craze appears to be running its course, like many another disease. Bankers and lawyers, manufacturers and dealers, all appear to have laid aside their usual business prudence and sagacity, and to have passed under the hypnotic spell of a set of men who never had any standing among the electrical fraternity, yet have the nerve to appear before a public meeting of interested citizens and there talk glibly about the enormous profits that will follow the building of a competing telephone plant to cost $30 or $40 a subscriber, though well aware that the plants they constantly refer to as ideal competing exchanges cost more than $100 a subscriber, and that the modern Bell exchange costs from $150 to $450 a subscriber, according to the population and the magnitude of the plant. These promoters will grow enthusiastic over the many plants they report as being in operation or in process of construction in many States, but will forget to say that not a single competing exchange has declared a clearly earned dividend, and will be very silent on the large amounts lost forever in the thirty or more competing exchanges that have fizzled out. Can the promoters point to a single one of these many exchanges that have been closed or sold out, from which the original investors ever received back one-fifth of their investment, to say nothing about dividends? Yet, in many cases, these investments represented the earnings of the widow, the orphan, the toiler in many lines of industry. This class of investors may be credulous, and may rarely fight for their rights; but it is doubtful if

they ever forget the names of the good citizens who blindly helped the stranger promoter to line his own pockets with the savings set aside for times of stress. Who ever heard of a stock promoter telling about the men whose political future has been blasted by allowing their names to be used to further the promotion of fraudulent schemes to the detriment of citizen and city? Yet the plain people have a sharp memory. And does not the investor pass by the town or city whose leaders are thoughtless of the vested rights of their taxpayers, hesitate not to ignore the opinions of the judiciary, and find pleasure in aiding the promotion of schemes foreloomed to failure?

FRED DE LAND.

Another Opportunity to Destroy Confidence. The successful demonstration of the utility and commercial value of an ingenious protective device, the general introduction of which will probably render obsolete the product heretofore turned out by a great industry, and completely revolutionize existing methods of construction, affords a golden opportunity to further destroy confidence in electrical investments and incidentally to line the pockets of the legal fraternity. For the device is so simple in character, and the adaptations and combinations of old and well-tried mechanism and processes is so apparent, that every tinkering expert will stand ready for a goodly consideration — to show envious and dishonest manufacturers how all that is contained in this device was incorporated in a dozen earlier patents; hence, in the opinion of the tinkering expert, the courts will not sustain the patent. But, as the device is original in character, possesses utility and novelty, we have little doubt but that in the event of a suit the courts will again hold that "The arrangements of all the elements to secure the object desired involves patentable invention of a high order, and that this device is an ingenious and highly useful combination." Of course, there will be a strong effort to tear down and destroy, but our judiciary may be relied upon to uphold the right, and to declare that "The moment the solution of the problem is made plain, those who did not see it seek to belittle the achievement of the one man who did see it, by the assertion that it was so exceedingly obvious and simple as to exclude the possibility of a demand upon the inventive faculties. This will not do. An invention does not cease to be meri-

torious because it is simple. Many of the greatest inventions are most simple. The test should be not whether the mechanism is simple or complex, but whether the patentee has given the world something new; whether the public is richer for his contribution to the art; whether he has produced novel and beneficial results." And this recalls Mr. Lockwood's apt and witty answer in a certain infringement suit: "Little further comment is required, but it may be added that the same line of reasoning which was adopted by Mr. Expert in discussing that patent is available to prove that the electro-magnet as it left the hands of its great inventor, Professor Henry, is a complete anticipation of the dynamo-electric machine, invented many years thereafter; and adopting such reasoning, we may say that by extending the core of the said electro-magnet at both ends, turning the same into journals, providing bearings wherein the said journals shall revolve, and by placing the magnet so altered, between the poles of a horseshoe permanent magnet or electro-magnet, and then by mounting a pulley or a crank on one end of the core of the first magnet, and by connecting its coils in the desired way, with the coils of the electro-magnet between whose poles the first magnet is placed, we thus have a complete anticipation of the invention of the dynamo. And it is not difficult to prove in the same logical manner that a boa constrictor is exactly the same thing as an elephant; for it may with a good show of reason be said that by simply cutting off twelve feet of the serpent's tail and sewing it on to his head, and by providing him with four legs and a new tail, and by giving him a pair of tusks and fitting him internally to eat grass and hay, we thus have a complete anticipation of the elephant."

FRED DE LAND.

Protecting Trade-Marks. Earnest support should be given to the H. R. Bill, No. 7477, now in the United States Senate, and which has been read twice and referred to the Committee on Patents, to provide for the registration of trade-marks on containers. This bill merely aims to make the federal legislation regarding trade-marks apply to those marks which are used in interstate commerce as well as those which are used in commerce with foreign nations or Indian tribes. The original trade-mark legislation by Congress in 1870 did not require that the person desiring to obtain protection by means of registration of his trade-mark

should be engaged in commerce, but was based upon the authority given to Congress by the Constitution "to promote the progress of science and useful arts by securing for a limited time to authors and inventors the exclusive right to their writings and discoveries." The Supreme Court in the trade-mark cases (100 U. S. [illegible]) found the legislation unconstitutional, and said: "When, therefore, Congress undertakes to enact a law which can only be valid as a regulation of commerce, it is reasonable to expect to find in the face of the law or from its essential nature, that it is a regulation of commerce with foreign nations or among the several States, or with the Indian tribes. If not so limited, it is in excess of the power of Congress. If its main purpose is to establish a regulation applicable to all trade, to commerce at all points, especially if it be apparent that it is designed to govern the commerce only between citizens of the same State, it is obviously the exercise of a power not confided to Congress." In amending the law to obviate the objection raised by the Supreme Court, Congress, perhaps through a misconception of the decision of the court, restricted the application and protection of the statute to trade-marks used *in commerce with foreign nations, or with the Indian tribes*. There is no reason for this. The power of Congress extends, as is sufficiently clear from the language of the Supreme Court, to commerce between the States as well as to foreign commerce or commerce with Indian tribes. As the law stands, it is incongruous and should be amended as is proposed in the bill referred to.

FRED DE LAND.

The Street Railway Convention. The St. Louis meeting of the American Street Railway Association, to be held October 20–23, promises to be the most important convention in the history of the association. The intention is to make it a business meeting, and while the social side will not be neglected, an earnest effort will be made to devote as much time as possible to solving problems that vex street railway officials. That the supplymen expect a large attendance is indicated by the extensive exhibit they are planning. The delegates from Chicago and the North and Northwest have arranged to make the trip in a special Wabash train, to be in charge of Mr. N. C. Keeran, city passenger agent of the Wabash lines, who carried the western delegation into Montreal four hours ahead of schedule time.

F. DE L.

Electrical Engineering

NOVEMBER, 1896.

SUPERHEATED STEAM.

BY W. E. BURGESS.

During the last few years there has been a steady but slow advance in the use of superheated steam; never wholly abandoned in Alsace, where it was first popularized by Hirn, it has gradually been divested of the worst troubles attending its use, and today there are quite a number of large installations both of isolated plants and central stations where the superheater has taken its place with feed-water heaters, forced draft, economizers and the other necessary adjuncts of the station that has any pretensions to economy. The writer proposes in the following articles to show clearly in what way the use of superheated steam increases the economy in the engine, to give the best methods of investigating and comparing the performance of engines using both saturated and superheated steam, by means of heat charts; to examine the actual efficiencies of engines using superheated steam, and discuss the influence of the superheater on the general economy of the power station.

In the first place, in order to obtain a clear understanding as to what superheated steam really is, let us suppose a cylinder open at the top containing a piston loaded with weights, giving with the pressure of the atmosphere P pounds per square foot of the area of the piston, and let this piston rest on the top of a quantity of water, say one pound, this water being at the temperature of melting ice, namely 32° Fahr. We will now apply heat to the vessel with the result that the temperature rises, and but for a very small rise due to the expansion of the water the piston remains stationary until a certain temperature has been reached, dependent on the pressure P. The temperature will now remain stationary at this limit and the formation of steam commences,

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the piston rising as the evaporation continues, and more and more of the water becomes steam; this continues until all of the water contained in the cylinder becomes steam, and the temperature which has remained constant until this point has been reached again commences to rise, and may be raised any amount if sufficient heat is added. This last stage or condition is the one which we propose chiefly to consider.

If the above process had been stopped when every drop of water was evaporated and nothing remained but steam, while care had been taken to prevent any further application of heat when all the water disappeared, so that the temperature was still stationary, the steam produced under such conditions would have had the greatest density possible in perfectly dry steam at the given pressure P, and such steam is called "saturated steam" or steam of "maximum density," and its temperature is the lowest possible at that particular pressure. Steam very seldom exists under such conditions, however, since it is generally more or less mixed with water, or else its temperature is higher than that corresponding to its saturated condition, that is to say it is superheated, or in a state corresponding to our third stage in our ideal cylinder.

There are other ways of producing superheated steam than by direct application of heat to the containing vessel, the most common method employed being "wiredrawing" from a higher pressure to a lower one. This is used, where a high pressure is [illegible] or when the amount of superheat required is not excessive [illegible] when the initial steam is comparatively dry, and in [illegible] this method was employed by the writer in [illegible] simple condensing Willans [illegible] W. Willans, the results [illegible] It may be incidentally mentioned [illegible] engines when working at [illegible] exert produce superheat [illegible] the governor valve and [illegible] higher than if they [illegible] using simple saturated [illegible] in the steam chest. The [illegible] this method [illegible] steam if the [illegible] superheat steam is

.48, a value given by Regnault and deduced by him from experiments made on steam at atmospheric pressure only. For example: Suppose the pressure on the boiler side of the reducing valve is 155 pounds gauge, and that the steam is perfectly dry, the total heat in this steam, if it were merely saturated, would be 1,194.25 thermal units, and let this steam be wiredrawn until the pressure is reduced to 55 pounds gauge, then the temperature of this steam, if it was merely saturated steam, would be 302.77° Fahr., and its total heat 1,174.28 thermal units, leaving a balance of heat unaccounted for of 20 thermal units; and since the specific heat of superheated steam at constant pressure is .48, this would indicate a rise of temperature of about 41.5° Fahr. if there were no loss by radiation, and the temperature of the steam would approximate to 344.27° Fahr. In practice it would, of course, be slightly lower than this. It will be seen from what has been written above that there is theoretically no limit to the amount of heat that can be stored in superheated steam, the temperature constantly rising with each addition of heat, and for years no experiments in the use of superheated steam were made, chiefly from apprehension of the working parts of the engine exposed to the heat being damaged by the high temperatures involved. Superheaters were certainly used in some instances, but generally in connection with boilers of such a design that the steam supplied was initially wet, and consequently the amount of superheat was not great, although the economy was considerable, due to the drying of the steam and the increased efficiency of the boiler; any high degree of superheat was, however, seldom found, and when it was used considerable damage was caused to the cylinders and the working parts of the engine. Indirectly, of course, this was due to the use of high temperature steam, but really the actual cause of the damage should be assigned to the improper lubricants in use at that time and to the large variation in the quality of steam supplied to the engine.

The lubricants in use were chiefly animal fats, which decomposed and lost all lubricating power at comparatively low temperatures and became utterly useless. When higher steam pressures were introduced these lubricants were compelled to give way to mineral oils, and the packings and glands of the engines were changed from fibrous material to metallic rings. The same troubles attended the introduction of higher steam pressures that had

[illegible] showed themselves in the use of superheated steam, [illegible] in a somewhat lesser degree, as the steam being in the superheated condition very small particles of water were carried over in suspension, and these no doubt added to the lubrication.

With the advent of the new lubricants it might seem that the use of superheated steam would have received a new impulse, but it has always dropped out of use, and engineers were so fully [illegible] in developing the compound and triple expansion engine, in utilizing the higher pressures available and in studying the effect of increased speed that attention was diverted from this method of reducing waste and increasing economy until recently, when once more its advantages seem likely to receive that consideration of their merit.

In studying the action of steam in the steam engine, the use of [illegible] charts first introduced practically by McFarlane Grey and [illegible] so much by the late P. W. Willans in his researches and investigations is in the opinion of the writer, the only practical [illegible] procedure. Indeed it is to the thermodynamic study of the steam engine what the indicator diagram in its usual form is to the mechanical study. By its use the transformations of [illegible] the engine can be carefully examined and the action of [illegible] walls, jacketing and superheating explained graphically [illegible] with ease.

Thermodynamically, when the values of any three of the quantities connected with a hot body are known, the state of that body is completely determined. Thus if the pressure, volume and temperature of the body are known, the condition of the body is also completely known; in the same way, if the temperature, volume [illegible] are known, the condition of the body is determined. [illegible] well known gases the relation between the pressure and [illegible] have been experimentally determined, and in the case of [illegible] corresponding relation has been obtained. For steam and [illegible] therefore, it is easily seen that only two of the quan[illegible] required to give us complete information with regard to [illegible]

[illegible] indicator card or pressure volume curve is the [illegible] form in which the changes which take place in an [illegible] presented to us, but these curves give us information [illegible] to the thermodynamic changes which are [illegible] in an indirect way, and the interesting points of

cylinder condensation or the action of the cylinder walls on incoming steam, superheating and jacketing are not readily or easily examined by means of these diagrams drawn by the engine itself. By taking as ordinates of a new curve, the temperature, and what is called the entropy of a gas for the abscissa, a new diagram can be drawn which shows all the transformations of the working fluid graphically, and which shows readily where and when heat is lost or regained during the working cycle of the fluid. The first thing necessary in order to understand the heat chart when plotted in this form is to get a clear knowledge of the meaning of the word "entropy," and to disabuse oneself of the idea that because the word is unfamiliar and mathematical that which it represents is necessarily abstruse or difficult of comprehension.

We will therefore consider the physical meaning of the term "entropy," and show how this quantity is calculated in the case of steam and water.

Suppose a body of an absolute temperature T—that is, a temperature measured from a zero of 460° below the ordinary zero on a Fahrenheit thermometer—and let a small quantity of heat be added to the body, say, x thermal units; this will, of course, increase its temperature. Now, if we divide the heat thus added by the temperature at which it is added, we obtain a quotient which is called the entropy of the body for the change considered. Taking water for an example, we obtain the entropy of the body by continuously adding minute quantities of heat and dividing by the temperature at which these small quantities of heat are added. In this way we obtain a large number of infinitely small quotients, and these, added together mathematically, give the result required. For instance, if we commence adding heat at a temperature T_1 to the water and cease when its temperature has reached T_2, the entropy for one pound of water, supposing the specific heat to be unity, will be mathematically expressed by $\log_\epsilon \frac{T_2}{T_1}$. When the temperature of the water reaches the boiling point (this of course depends on the pressure to which it is subjected), the temperature of the water no longer continues to rise, as any further addition of heat causes the formation of steam. From any steam tables the amount of heat necessary to convert one pound of water into steam at a given temperature can be obtained, and

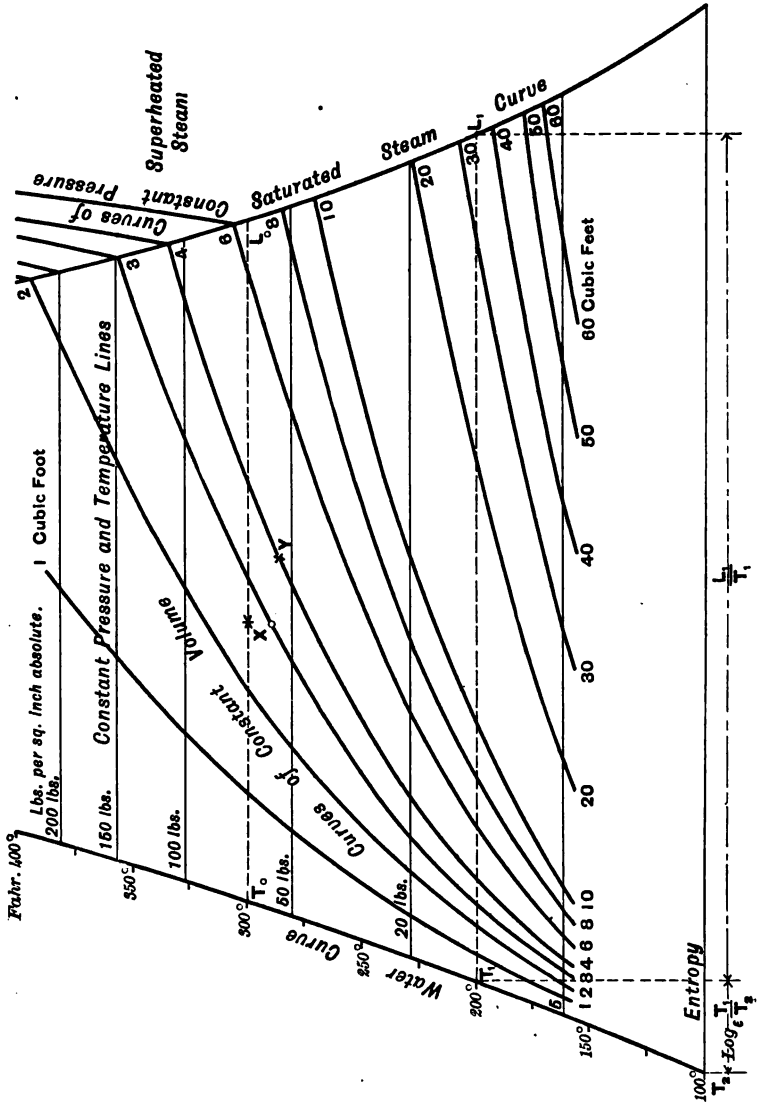
Fahr. 400°
Lbs. per sq. inch absolute.
200 lbs.
150 lbs.
100 lbs.
50 lbs.
20 lbs.
1 Cubic Foot
Constant Pressure and Temperature Lines
Volume
Curves of Constant
Water Curve
Curves of Constant Pressure
Saturated Steam
Superheated Steam
Curve
60 Cubic Feet
Entropy
550°
300°
250°
200°
150°
100°

FIG. 1.

this quantity divided by the temperature at which the steam is formed is the entropy of the steam under consideration.

In constructing the heat chart for practical use it is usually sufficient to calculate the entropy from 100° Fahr., and in this chart the ordinates represent temperature and the base line entropy. In Fig. 1 the curve on the left-hand side of the diagram is first drawn, this being the water curve, and it is plotted by obtaining values of $\log_\varepsilon \frac{T_1}{T_2}$ at intervals of a few degrees for the whole temperature range decided upon — usually from 100° Fahr. to 380° or 400° Fahr. The entropy of the steam is then determined for these same temperatures by obtaining, from a table of the properties of steam, the latent heat of one pound of steam at each temperature and dividing by that temperature; the values thus obtained are the horizontal lengths between the two curves, the curve on the right hand being obtained by plotting all these values horizontally from the top of each temperature ordinate and joining the points thus found by a continuous curve. This curved line represents the expansion of dry saturated steam which is kept in a state of saturation by addition of heat to the cylinder, and it is the exact equivalent of the saturation curves plotted on the pressure volume diagrams for comparison with the curve traced by the indicator pencil.

In the diagram, $T_0 L_0$ represents the entropy of steam at a temperature T_0, and the fluid at T_0 is wholly water and at L_0 it is wholly steam. At any intermediate point along the horizontal line $T_0 L_0$ the fluid consists of a certain proportion of steam and a certain proportion of water, which is given by the ratio $\frac{T_0 X_0}{T_0 L_0}$ and this is what is called in the study of the steam engine the dryness fraction, and by means of these dryness fractions the expansion curve of any indicator diagram can be transferred to the heat chart. There is another method of transferring the whole indicator diagram to the heat chart which is, however, much more convenient, i. e., by means of constant volume curves. These curves were first added to the diagram by Captain Sankey, and, with the addition of constant pressure lines, give a very complete diagram for the solution of thermodynamic problems. The meaning of any area in the field of the diagram bounded by the two curves can be shown as follows: Take any rectangle *a b c d*

[illegible] Fig. 2. Then [illegible] and [illegible] represent the absolute temperatures of the steam and [illegible] and [illegible] represent the change in entropy of the steam [illegible] the addition of heat [illegible] and by our definition of entropy [illegible] is equal to [illegible] divided by the temperature [illegible], or the total heat expended is equal to the product [illegible]. In the same manner [illegible] by the temperature [illegible] the total heat expended is equal to [illegible] the rectangle [illegible], and the heat required to produce the change between the two states denoted by the lines [illegible] and [illegible] is [illegible] by the area of the rectangle. Constant pressure lines are represented on the diagram by horizontal lines, and changes along these lines are also changes which take place at constant temperature. This can be seen to be so from the nature of the diagram. These changes are called isothermal changes and correspond to isothermal expansion or compression on the pressure volume diagram. It is also easily seen that a vertical straight line in the diagram merely represents a change in which the entropy of the steam remains constant, and, as the definition of entropy given above is heat added divided by the temperature at which such addition takes place, a constant entropy expresses the fact that heat is neither added nor subtracted from the steam during its change of state. Such changes are called adiabatic changes. The curved lines from left to right, curving in an upward direction on the diagram, are the constant volume lines due to Captain Sankey, R. E., and they are of great practical value in showing the actual volume of steam at any particular stage. These lines give for any mixture of steam and water the temperature, volume and total heat required to produce such a mixture. For instance, let us follow one of these constant volume lines — starting at the saturation curve at, say, 100 pounds pressure, the volume of one pound of steam is very closely four cubic feet, and following the curve along to a point D, it will be seen that when only one-half of the water had been evaporated into steam, the remaining half still being water, the pressure was about fifty-two pounds. In like manner the volume, pressure and temperature of that portion of the water which was steam can be read off from the chart for any point within its limits.

Up to the present we have only been considering that portion of the diagram which lies between the two curves; but if the steam becomes superheated — that is, if it contains more heat for a given pressure than ordinary saturated steam—the state of the fluid

is given by state-points in that portion of the diagram to the right of the saturation curve, and constant pressure lines can be drawn in this part of the chart, which are now no longer horizontal as in the case of ordinary steam, but which rise at an angle, the temperature increasing with each addition of heat to the steam. These constant pressure lines can be drawn on the diagram when the assumption is made that the specific heat Cp at constant pressure of superheated steam is .48, in exactly the same way that the water curve was drawn. The entropy being $c \log_\varepsilon \frac{T_1}{T_2}$ and the area inclosed below the curve by the two verticals, T_1 T_2 is equal to the amount of heat added to the steam to superheat it from T_2 to T_1° Fahr. These curves are plotted in exactly the same manner as the water curve previously described.

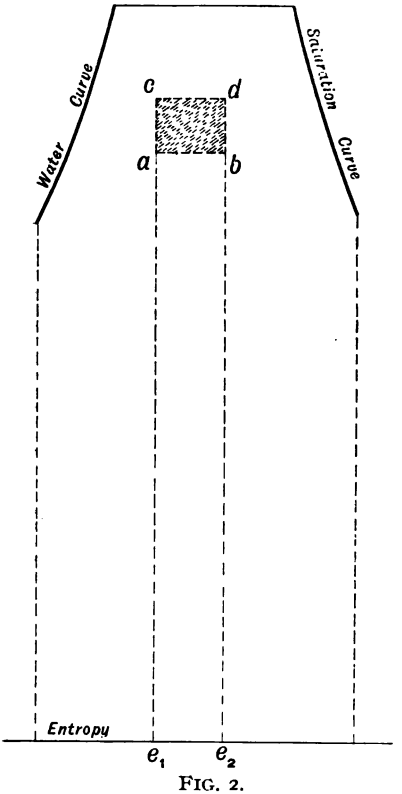

FIG. 2.

Having now completely determined our diagram or heat chart, the next step is to show how to transfer the ordinary indicator diagram to it, in order that we may see graphically the behavior of steam from a thermodynamical point of view in the steam engine. It is hardly necessary to add here that when once the heat chart has been drawn it can be used an indefinite number of times by simply placing tracing paper over it and transferring those portions that are required for any immediate investigations; and this is the usual way in which the diagram is employed practically, as considerable time is required for plotting the original.

SOME NOTES ON FLY WHEELS.

IRVING A. TAYLOR.

There are some points in Mr. Williams' contribution on fly wheels in the August number of ELECTRICAL ENGINEERING which may not have been carefully considered, and which are of such importance that they should not be passed over unnoticed.

Let us take the following symbols:

R = revolutions per minute.

V = velocity in feet per minute of circle of revolution.

v = velocity in feet per second of circle of revolution.

D = diameter of circle of revolution in feet.

W = weight of rim in pounds.

w = weight of material of rim in pounds per cubic foot.

F = centrifugal force in pounds.

A = cross-sectional area of rim in square feet.

s = *safe* tensile stress of material in pounds per square foot.

S = stress tending to pull one half the wheel from the other half.

As the stress (S) is supported in two places, one at each end of a diameter, the stress on any cross-section of a wheel will be $\frac{S}{2}$

On page 69 I find: "Centrifugal force does not vary directly with the periphery velocity of a wheel." Taking the writer's formula "$F = \frac{R^2 D W}{5,870}$" (1)

and remembering that $V^2 = R^2 D^2 \pi^2$ or $R^2 D = \frac{V^2}{D \pi^2}$

we have, substituting this value of $R^2 D$ in equation (1),

$$F = \frac{V^2 W}{D \pi^2 5,870} = \frac{V^2 W}{D\, 58,000} \qquad (2)$$

This shows that $F \propto \frac{V^2 W}{D}$, i. e., that the centrifugal force varies as the square of the peripheral velocity, as the weight, and

inversely as the diameter, as does also the stress (S), as can be seen by formula (3).

$$S = \frac{F}{\pi}$$

substituting the values of F from equations (1) and (2), we have

$$S = \frac{R^2 D W}{18,430} = \frac{V^2 W}{182,200 D} \qquad (3)$$

Equation (3) would seem to show that, as S varies inversely as D, we should, with a constant velocity and a smaller diameter, have to have a stronger wheel in order to stand the increased stress; but this is not so, as a decrease in the diameter (D) means a proportionate decrease in the weight (W) or else a larger area (A) to stand the stress.

The following reasoning will make it clear that the safe velocity (V or v) of a wheel depends only on s and w.

As the stress across any cross-sectional area (A) of the rim is $\frac{S}{2}$, the safe stress per square foot of the area is

$$s = \frac{S}{2A} \text{ and } S = 2As \qquad (4)$$

Also $$W = \pi D A w \qquad (5)$$

and substituting the values of S and W, found in equations (4) and (5), in equation (3), we have

$$2As = \frac{V^2 \pi D A w}{182,200 D} \text{ or } s = \frac{V^2 \pi w}{364,400}$$

Solving for V, we have

$$V = \sqrt{\frac{364,400\, s}{\pi w}} \qquad (6)$$

$$\text{As } v = \frac{V}{60} \therefore v = \sqrt{\frac{364,400\, s}{\pi w (60)^2}} = \sqrt{\frac{32.187\, s}{w}} \qquad (7)$$

The constant 32.187 in equation (7) is commonly known as "g." In cast iron, letting $s = 500,000$ pounds per square foot and $w = 450$ pounds per cubic foot, we have for the maximum safe velocity

$$v = \sqrt{\frac{32.187 \times 500,000}{450}} = 189 \text{ feet per second.}$$

The average in most fly wheels is about 100 feet per second.

The foregoing considerations do not take into account the beam action on that part of the rim adjacent to the clamping

lugs in split wheels. It seems needless to say that this should always be done.

We will now consider the beginning of the last paragraph on page 70: "The efficiency of a wheel depends upon the velocity of rim, that is to say, 1,000 pounds, for example, at 5,000 feet per minute, is just as efficient as 2,000 pounds at 2,500 feet per minute." On page 73 we find that "W should equal $\frac{120,000}{V}$" Just above this formula the writer says in substance: If a wheel rim is moving at $V = 6,000$ feet, the *force* of one kilowatt tending to stop it is equal to 7.37 pounds. But if we should suppose that the wheel is moving at 12,000 feet per minute and one kilowatt is still being delivered, the force of resistance would be only $\frac{7.37}{2} = 3.685$ pounds, or one-half what it was before, and the force in the wheel would, according to the writer's formula on page 72, $\left(F = \frac{WV}{g}\right)$, be just twice as much as when V was 6,000 feet; we should therefore have a double force in the wheel acting against a half-force in the dynamo or other resistance, and it would therefore take four times as long to stop the wheel, i. e., the time taken to slow the wheel down by a given percentage of its average speed would, if that percentage is not large, vary as the square of the velocity instead of as the first power of the velocity, as the parts quoted imply. This will be clear to everyone who considers that a fly wheel supplies *energy* not "*force*" to a dynamo, and that the energy of a moving particle (every moving particle in the fly wheel) is equal to $\frac{1}{2} m v^2$, where m is the mass of the particle in pounds, v is the velocity in feet per second and the energy is stated in foot poundals.

As I am not an engineer, I shall refrain from going deeply into the subject, but will just indicate the path by which the relation between evenness of rotation, load and steam diagrams, and velocity and weight of the wheel may be found.

There will be a certain period during which the energy supplied to the wheel exceeds the energy taken from it, and energy will be stored in the wheel in the form of a slightly increased velocity; this will be followed by a period in which the reverse state of affairs will take place; thus the wheel, though having a mean velocity (v), will fluctuate between a maximum velocity

(v_1) and a minimum velocity (v_2). The difference between the energy of the wheel at its maximum velocity and the energy at its minimum velocity is exactly equal to the energy causing its velocity to vary; this is expressed in formula (1) following.

In addition to the foregoing symbols we will use the following:

e = energy in foot poundals causing the velocity of the wheel to change.

E = energy in foot pounds causing the velocity of the wheel to change.

ω = weight of rim plus about one-third of the weight of the arms, in pounds.

$$e = \omega \frac{v_1^2 - v_2^2}{2} \tag{1}$$

$$\therefore \qquad v_1 - v_2 = \frac{2e}{\omega(v_1 + v_2)} \tag{2}$$

As $v_1 - v_2$ must be small, the mean velocity (v) of the circle of revolution will be

$$v = \frac{v_1 + v_2}{2} \tag{3}$$

Dividing (2) by v, we have

$$\frac{v_1 - v_2}{v} = \frac{e}{\omega v^2} \tag{4}$$

The expression $\frac{v_1 - v_2}{v}$ is the ratio of the variation of speed to the mean speed, i. e., the *percentage* of speed variation allowable in the wheel. For electric lighting some authorities place this percentage at .005 to .01, i. e., from one-half per cent to one per cent, while others make it still higher. My opinion on the subject is valueless. We will let

$$\frac{v_1 - v_2}{v} = \gamma$$

then, substituting in (4)

$$\gamma = \frac{e}{\omega v^2} \text{ or } \omega = \frac{e}{\gamma v^2}$$

or since $e = 32.187\,E$

$$\omega = \frac{32.187\,E}{\gamma v^2} \tag{5}$$

This equation shows that the weight (ω) of a wheel, calculated as explained under the definition of ω, varies directly as the

energy to be supplied by the wheel during any interval, and inversely as the percentage of speed fluctuation and the square of the velocity.

I might quote authorities who claim that E varies directly as D, but Rankine does not seem to think so, and indeed, in the light in which I view the matter, I do not see how the energy which it is necessary for the wheel to supply can depend on the proportions of it. It depends rather on the load diagram, the steam diagram, the weight and velocity of the other moving parts such as the piston, and especially the dynamo armature and the allowable variation of speed. But a full discussion of the various methods of determining the value of E in any given case would open a very wide field, and as I have already exceeded my limits, I will merely say in conclusion that I do not believe that any even approximate formula for the weight of a fly wheel of value to steam engine designers can be deduced without considering, at least to some extent, the steam diagram of the engine for which the wheel is designed.

THE DETERMINATION OF ZINC IN SAWDUST.

BY J. E. MOORE.

The preservation of wood is a subject to which considerable attention has been paid of late, particularly as a good many railroads are now using ties, and telephone and electric light companies are using conduits, which have been treated with some antiseptic to prolong their lives. Treating ties or conduits with chloride of zinc is considered one of the most effective ways for retarding decay, and attendant upon the increased use of this method is the importance of determining the amount of solution which is absorbed by the ties or conduits, which amount, owing to the great difference in porosity and consequently in power of absorption of various woods, is far from uniform.

Undoubtedly the best way to get a good average sample for analysis is to saw several times through the tie or conduit across the grain, saving all the sawdust therefrom and mixing it thoroughly. This is almost imperative, especially if the wood on which the analysis is to be made has been recently treated, for it has been shown that it takes time for the solution to work its way through to the middle. Determinations made on sawdust so obtained should show the average amount of zinc chloride present.

There is some difference in opinion among chemists as to the danger of losing zinc by volatilization when determining same in sawdust, if the method of burning the material to ash and subsequent treatment of the ash is used instead of extracting the zinc with acid and water. The writer has had some discussion with several others on the subject, and has found considerable disagreement as to the accuracy of the former method.

Probably the most objectionable point in the method of extracting the zinc (or rather chloride of zinc), by soaking a long time in dilute acid, is the fact that the resulting solution is so rich in organic matter to get rid of which necessitates rather long and tedious manipulation which not infrequently results in only partially successful elimination of same. Another objectionable feature is the large bulk of the solution, as the sawdust

has to be washed so thoroughly after treatment to insure it being entirely free from the zinc chloride.

A good many determinations have been made by both methods by the writer, and the results obtained show that by using sufficient care and taking enough time, the total amount of zinc chloride present in sawdust can be determined very accurately. The following gives the methods of procedure and the results of the experiments, using the method of first burning the material to ash.

In the first place a litre of nearly neutral chloride of zinc solution was made up and the amount of zinc chloride carefully determined thus:

Several portions of 10 c. c. each of the thoroughly mixed solution were acidulated with hydrochloric acid, and diluted to about 100 c. c. Sulphureted hydrogen gas was then passed for about forty minutes, and the resulting very slight precipitate filtered off. The filtrate was then evaporated to about 50 c. c. and any small amount of iron which may have been present was oxidized by the addition of a few drops of nitric acid. The iron and alumina (the amounts of which were very small) were then separated by a basic acetate precipitation and filtered off, the beaker being thoroughly rinsed and the filter washed several times with hot water. The bulk was then reduced to about 50 c. c. and five or six drops of glacial acetic acid added. The solution was brought to a boil and sulphureted hydrogen gas passed, while boiling for about twenty minutes. The precipitate, which was quite granular, was allowed to settle and then filtered off on a double paper, washed thoroughly with hot water, dried and ignited carefully in a porcelain crucible. When the crucible had cooled, the contents were mixed intimately with ammonium carbonate (pulverized) and cautiously heated up to bright red, several times, or until there was no change in weight on further treating. This gave zinc oxide which may be calculated to zinc chloride.

The method of procedure for determining zinc chloride in the sawdust was:

First, several portions of 50 grams each, of sawdust known to be free from zinc, were each treated with 10 c. c. of the zinc chloride solution, and each very thoroughly mixed.

Each 50-gram portion of the treated sawdust was placed in a

large evaporating dish, and this put on the hot plate; however, not directly over the flame, but rather on the cooler part of the plate. Then it was allowed to thoroughly char, but if at any time it showed a tendency to glow this was discouraged by covering over, so that the charring was very slow and with but very little actual burning. After this was finished it was placed on a triangle over a naked Bunsen flame, but about two inches above the tip of the flame. Then the ignition was made complete, but very slowly, by frequent stirring and allowing very little glowing till toward the end of the operation, when it was heated to a dull red for a few minutes, stirring constantly.

After cooling, the ash was treated with about twenty c. c. of strong hydrochloric acid and a little water, and the solution boiled with the addition of a few drops of strong nitric acid. When all action had ceased the solution was allowed to evaporate to dryness and bake at a low heat for about an hour. Then it was taken up with a little hydrochloric acid and water, and filtered from the siliceous matter, washing the paper several times. At this stage the bulk was made up to about 75 or 80 c. c. Then sulphureted hydrogen gas was passed for about five minutes, without, however, producing any precipitate. The solution was again boiled, the iron oxidized with a few drops of strong nitric acid, and the iron and alumina separated by a basic acetate precipitation. The determination from that point was carried on as described before.

The following are the results obtained on two sets of experiments:

FIRST EXPERIMENTS.	Grams zinc chloride.
1st 10 c. c. zinc chloride solution	0.941
2d " " " "	0.945
3d " " " "	0.934
1st portion 50 grams sawdust treated with 10 c. c. of the above	0.945
2d " " " " " " " "	0.943
3d " " " " " " " "	0.928
SECOND EXPERIMENTS.	
1st 10 c. c. zinc chloride solution	0.560
2d " " " "	0.548
3d " " " "	0.562
1st portion 50 grams sawdust treated with 10 c. c. of the above	0.552
2d " " " " " " " "	0.566
3d " " " " " " " "	0.534

A number of determinations were also made by extracting the zinc chloride from the treated sawdust as described before, and the results tallied very well with those tabulated above, but as before stated the operation was long and somewhat unsatisfactory.

Of course, the time required to properly burn the sawdust to ash is somewhat long, as it was found necessary to use considerable caution and to proceed slowly with the burning in order to avoid any loss by volatilization, but aside from this the method is comparatively short. On the other hand, the necessary time to extract the zinc chloride by leaching should be from twelve to twenty-four hours, and in addition to this, the elimination of the organic matter from the solution requires at the least several hours.

This is not written to set forth any new principles, but simply to give the experience of one who has had some trouble in determining zinc in sawdust and other substances, and it may possibly prove of some little use to a few who come in contact with similar difficulties.

TELEPHONE CABLES.

BY DR. V. WIETLISBACH, OF BERNE, SWITZERLAND.

RETARDATION — (*Continued.*)

Considering this great velocity there will be no fear of phase difference in neighboring cross sections of the two loop wires under normal conditions. It may be that the consonants with their irregular wave motions following each other in quick succession will not quite coincide, and thus produce charge effects. But by the action of self-induction a great difference of phase is produced when an electromagnet (e. g., telephone, induction coil, drop) is connected in on one wire. Hence on cable lines there should be no apparatus of any kind connected in series. Such instruments are always to be bridged across the two wires, and must, therefore, be specially constructed for the purpose.

Besides the condenser effect, polarization of the dielectric will be observed on metallic circuits, and all the more because the condenser effect is considerably reduced by the method of connection. For this reason, air or any other suitable gas is certainly the best insulating material, since all other liquid and solid insulators polarize more or less when used for metallic circuits, and, therefore, impair transmission. Thus the greatest difficulty with cables in telephony is the polarization of the dielectric. While on the ancient single-wire cables with tinfoil winding, conversation can only with difficulty be carried on over a length of 5 km. (3 miles), with metallic circuits the distance can be greatly increased.

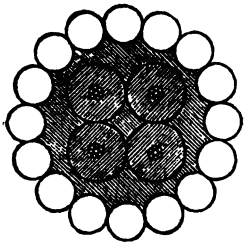

FIG. 213.

The longest telephone cable now in service is the one between Dover and Calais, having a length of about 40 km. (25 miles), and forming part of the Paris-London telephone line. This cable consists of four gutta-percha-covered conductors of the section shown in Fig. 213. Each conductor is composed of seven copper wires of 0.9 mm. (0.036 inch) diameter, having a resistance of 4 ohms per km. (6.4 ohms per mile). The capacity of

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[illegible]

[illegible]

each conductor is 0.164 microfarads per km. (0.2624 per mile), and the insulation about 1,000 megohms per km. (1,600 megohms per mile). Its iron armor consists of sixteen wires, each 7 mm. (0.28 inch) in diameter. The transmission over this cable is fairly good.

There is no doubt that conversation is possible over much longer cables, but definite conclusions are at present out of the question for want of opportunity for experiment.

In the construction of such cables two points call for special attention:

1. The insulating material must not be readily polarized, for then the current curve is altered. Gutta-percha is unfavorable in this respect, possessing a pretty high induction constant and a slow polarization moment.

2. The two lines of the pair should lie as close together as possible and be twisted around each other spirally, so as to avoid charging their environment. In this respect the Dover-Calais cable, modeled after a telegraph cable, is not advantageous.

It is ordinarily assumed that the electrostatic capacity of a metallic circuit amounts to one-half that of a single line, or one-fourth that of the total length of wire, but this is a wholly arbitrary assumption. If the two wires of a pair are put as close to each other as possible, the product CR then loses its importance, the value of C being taken as measured by the ordinary method. But in this case we should not overlook the electromagnetic induction of the paired wires on each other, for it has a favorable influence on transmission, partly neutralizing the effect of capacity.

It is to be noted that the above observations apply only to cables whose conductors are not surrounded by a grounded metallic screen to obviate induction. If two paired wires are surrounded by such a screen, their condenser capacity remains unchanged, the capacity of the pair being exactly twice that of each single wire, so that the retardation is not diminished by pairing, but doubled. Only cables whose conductors are twisted around each other without an intervening induction screen, and in which the second condenser plate lies outside the pair, can be improved by using metallic circuits.

In a concentric cable the copper core serves as one line, while a tubular envelope of copper wires forms the return, being

completely insulated from earth, like an ordinary return wire. Such double lines exert no electromagnetic induction on each other, for theoretically they behave as if the current flowed both ways in the core, its external effect being thus zero. A condenser effect is, however, possible, though to a much smaller degree than with single lines. I have tested concentric cables fifteen km. (nine miles) long, in the St. Gothard tunnel, through which conversation is very good.

The following are the specifications for the so-called "conference" cables, commonly used in America:

SPECIFICATIONS FOR UNDERGROUND CABLES.

Adopted by the Cable Committee, April 6, 1892.

1. *Conductors.*— Each conductor shall be .03589 inches in diameter (19 B. & S. gauge) and have a conductivity of ninety-eight per cent of that of pure soft copper.

2. *Core.*— The conductors shall be insulated, twisted in pairs, the length of the twist not to exceed three inches, and formed into a core arranged in reverse layers. In the case of dry-core cables, the ends of each length shall be filled with an insulating material capable of preventing the entrance or circulation of air in the cable. This insulating material must seal the cable for a distance of at least two feet on each side of the joint after the joint has been made.

3. *Sheath.*— The core shall be inclosed in a pipe composed of lead and tin, the amount of tin to be not less than three per cent. This pipe shall be formed around the core and have a thickness of ⅛ inch. The pipe shall be free from holes or other defects and of uniform thickness and composition.

4. *Electrostatic Capacity.*— The average electrostatic capacity shall not exceed .080 of a microfarad per mile, each wire being measured against all the rest and the sheath grounded; the electrostatic capacity of any wire so measured shall not exceed .085 of a microfarad per mile.

5. *Insulation Resistance.*— Each wire shall show an insulation of not less than 500 megohms per mile at 60° Fahr. when laid, spliced and connected to terminals ready for use, each wire being measured against all the rest and the sheath grounded.

6. *Conductor Resistance.*— Each conductor shall have a resistance of not more than 47 ohms at 60° Fahr. for each mile of cable after the cable is laid and connected to terminals.

7. *Guarantee of Electrical Conditions.*— The electrostatic capacity shall not increase nor shall the insulation decrease beyond the limits above specified for one year after the cable has been laid and spliced, except from mechanical injury.

8. *Covering for Pipe When Placed in Wooden Conduits.*— (1) The pipe shall be thoroughly coated with asphalt. (2) A protecting jacket shall be

laid on outside; this jacket to consist of at least two wrappings of tape put on in reversed layers and saturated with asphalt.

NOTE.—The committee desires to call attention to the following points:

First, That cables should be so constructed as to allow them, when desired, to be withdrawn from the conduits for use elsewhere. To this end the specifications have been modified so as to reduce the liability to buckling, but care should always be exercised in handling to guard against this danger, and preference should be given to cables least liable to injury from this cause.

Second, Preference should be given to cables possessing a capacity lower than .080 of a microfarad per mile, provided the requirements of the specifications in other respects are fulfilled.

On the basis of the capacity specifications it is expected that 100 pairs of conductors can be placed in a pipe not exceeding 2½ inches outside diameter; 60 pairs of conductors can be placed in a pipe not exceeding 2 inches outside diameter; 50 pairs of conductors can be placed in a pipe not exceeding 1⅞ inches outside diameter.

Third, The durability of cables depends so largely upon the character of the joints that the committee recommends the utmost care in making splices and in drying the core before a joint is sealed.

It is also recommended that at each joint the relative position of the pairs be changed.

A later specification reads:

3. *Sheath.*—The core shall be inclosed in a pipe composed of a homogeneous mixture of lead and tin, in the proportions of about three per cent (3%) by weight of tin to about ninety-seven per cent (97%) of lead. The amount of tin contained in any sample shall not be less than two and five-tenths per cent ($2\frac{5}{10}$%) nor more than three and five-tenths per cent ($3\frac{5}{10}$%).

[Whether a homogeneous mixture of the tin and the lead can be made is a mooted question with some manufacturers.]

Ordinarily 120 wires or 60 pairs are twisted into one cable, corresponding to the arrangement of multiple boards in which twenty lines are bunched together and connected to one row of jacks. The very large cables contain 100 to 150 pairs and are made in lengths of about 150 m. (500 feet).

3.—*Methods of Cable Laying.*

Cables may be suspended in the air or buried in the ground.

a. AERIAL CABLES.

The suspension of cables in the air is a transition stage between overhead wires and underground cables, and is resorted to when [illegible] more bare wires can be strung overhead, be it for want of [illegible] pole lines or for want of available roofs for fixtures, or [illegible] reason, but always where the cables cannot be

placed underground for the time being. Want of space will apply usually to the vicinity of the exchange, but at some distance room for new lines is generally found. Therefore cables are run from the exchange to suitable roofs in the neighborhood and thence carried further to ordinary fixtures as open lines. A cable will not support its own weight over an ordinary span because of its low tensile strength, but even were its tensile strength sufficient, the sag would be far too great. To this end a steel wire rope is run between the supports and provided with suspending hooks or clips, usually made of zinc, to obviate corrosion, shaped as represented in Fig. 214 and placed about 1 meter (in America usually 2 feet) apart. A one-piece malleable iron hanger is shown in Fig. 215. The edges are beveled so as not to cut the sheath, and it may be easily applied with a special tongs and made to grip the cable firmly. The spans thus made seldom exceed 100 m. The size of the suspending wire, of course, depends on the load it has to carry, i. e. on the weight of the cable and the length of span, and in calculating the load the tension at the supports must be considered also. For light cables and short spans a 3 to 5 mm. ($\frac{1}{8}$ to $\frac{1}{5}$ inch) steel wire may suffice, but for heavy cables only steel-wire rope is used. The size of the suspending wire may be calculated by the following formula in which:

FIG. 214.

FIG. 215.

$C =$ the cross section of the suspending wire in square inches.

$W =$ the weight in pounds per foot of the cable to be suspended.

$l =$ the length between supports in feet.

$y =$ the sag in feet.

Then $C = \frac{Wl^2}{80{,}000\,y}$

[illegible]

[illegible] the making and the [illegible] would [illegible] the atmosphere.

[illegible] a small percentage of tin adds to the [illegible] and it is usual to specify [illegible] have to be drawn into con- [illegible] to severe strain. The admixture of [illegible] more difficult to manufacture, straining the [illegible] that breakdowns become frequent.

METHODS OF FUEL TESTING.*

BY ARTHUR V. ABBOTT, C.E., AND FRANZ J. DOMMERQUE, M.E.

As the fuel supply of the world certainly ranks next in importance to the food supply, it seems strange that it has only been within the last decade that attempts have been made to systematically and accurately examine the qualities of fuels and determine their relative value for the process of combustion. Commercial transactions in all forms of ores are invariably based upon the metallic content of the desirable constituent. So, ores of iron, gold, silver, etc., are bought and sold entirely by such an analysis as will indicate to the purchaser the probable content of the metal sought. It is not improper to class coal as an ore of carbon or carbon and hydrogen, and under this category it is advantageous, both to the buyer and the seller, that the price per unit weight of fuel should be strictly in accordance with the combustible elements contained. In Europe the practice of selling fuel by calorific power has already attained considerable currency and is rapidly extending. If it were true that commercial fuels contained carbon only, the process of determining the calorific power, and, consequently, the value to the purchaser, would be a matter of exceeding ease. Unfortunately, the volatile constituents, hydrogen, oxygen and nitrogen, vary the fuel value to a great extent and introduce numerous complications and difficulties to an accurate and just estimation of calorific power.

Two methods are in vogue for the determination of calorific power. By one a chemical analysis is made and the calorific value calculated from the known heating power of the combustible elements. If, under all circumstances, the various fuel elements exercised the same calorific power, this method could always be relied upon to give accurate and trustworthy results. Unfortunately, these elements vary somewhat in their calorific

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power's depending probably upon some obscure molecular condition at present not fully understood. An experiment shows that the fuel elements vary slightly in their heating powers, depending upon the source from which the test samples are derived. In the exception of the hardest anthracite, all the commercial fuels contain a notable proportion of volatile constituents, consisting of hydrocarbon compounds containing more or less oxygen and nitrogen. It is usually considered that the oxygen is already in combination with a sufficiency of hydrogen to satisfy its chemical affinity, and that the nitrogen with its usual inertness plays a negative part. At best the chemistry of hydrocarbon compounds is still but vaguely comprehended, and the variation in calorific power of combustibles having parallel analyses is sufficient to seriously invalidate this view. However this may be, there is at present sufficient experience to show that analytical results, when properly conducted, may be depended on within a probable error of 3 to 4 per cent.

By the second method an accurately measured sample of the fuel is burned and the actual calorific power developed by its combustion, directly measured. From all standpoints, this method is by far the most desirable, as it presents the simplest, most certain and easiest manipulations, and indicates the calorific power of the fuel directly, without introducing errors due to possible allotropism in chemical combinations. It is feasible by the analytical method to determine, more or less completely, at the pleasure of the operator, the various constituents of any fuel. For coal and wood the determination of the quantity of moisture, ash, volatile matter and fixed carbon is most frequently made. To ascertain the quantity of moisture is comparatively an easy and simple operation, requiring no apparatus beyond a fairly accurate platform scale, a large pan and a convenient place such as the top of a boiler upon which the sample to be analyzed can be dried. The operation consists in taking a fairly large sample, containing from twenty-five to fifty pounds, and after weighing it carefully, placing it where it may be kept at a temperature not to exceed 100° Fah. for a period of twenty-four hours. At the end of this time the moisture may be considered as entirely expelled, and, by weighing, the quantity of moisture is at once obtained. The process thus outlined is somewhat crude and is liable to error, as the exposed pan may collect more or less dust and

dirt from the boiler room; and as the temperature cannot be accurately controlled, some of the moisture may remain, due to too low a desiccation, or a small proportion of the volatile matter may be expelled and a portion of the coal oxidized if it is too high. However, as the content of moisture affects markedly the calorific power, and as the platform scale and tin pan are pieces of apparatus always at the command of every central station, this test so readily and easily applied is of value in determining approximately the quality of the fuel. It is, however, much more satisfactory to make what is termed a proximate analysis of the fuel, which in the case of coal or wood may be easily accomplished. The apparatus required consists in a reasonably accurate balance capable of weighing to a single milligramme, a platinum crucible, a retort stand, water bath, argand Bunsen burner and agate mortar.

The expense of the necessary apparatus will stand as follows:

TABLE No. 67.—EXPENSE OF APPARATUS FOR PROXIMATE ANALYSIS.

Balance	$25.00 to $50.00
Platinum crucible	10.00
Retort stand	2.50
Water bath	2.50
Bunsen burner and rubber	2.50
Agate mortar	5 00
Total	$57.50 to $77.50

The operation of making a proximate analysis of coal consists in weighing, from a carefully selected sample, a specimen from five to ten grammes in weight. Previous to weighing, the sample should be carefully pulverized to reduce it to an impalpable powder. The assay sample is then introduced into the platinum crucible, which has previously been carefully cleaned, ignited and weighed. It is then placed in the water bath and maintained at a temperature of 212° Fahr. until the crucible, when thoroughly cooled, ceases to show any decrease in weight. This is usually accomplished in from one to six hours. It occasionally happens with some samples of coal that some volatile constituents are expelled by prolonged heating at 212°, though if the process is carefully conducted this rarely occurs.

The difference between the original weight of the sample and that obtained after desiccation in the water bath is the content of contained moisture. The platinum cover is now placed upon the crucible in order to prevent the access of air, and the whole crucible ignited at a bright red heat for half an hour. By this means all the volatile constituents of the coal are expelled, the fixed carbon and the ash alone remaining. As soon as the ignition is accomplished and the crucible carefully cooled, a second reweighing determines the percentage of volatile constituents. The crucible containing the fixed carbon and ash is now uncovered and placed over the flame of the Bunsen burner, in such a way as to fully ignite the residue, at the same time allowing the lamp flame to play over the edge of the crucible in such a way as to cause a stream of air to impinge upon the glowing carbon. In the course of half an hour the carbon will be entirely consumed, leaving in the crucible only the ash. The third weighing, after the crucible is cooled, determines the quantity of ash and completes the analysis. Caution should be preserved in cooling the crucible, by placing it under a jar in which a little chloride of calcium is placed, in order that it may be cooled, free from the moisture which normally is present in the air, or otherwise there is a possibility of a slight vitiation of the results, due to the absorption of moisture.

Upon the completion of the analysis the crucible should be carefully cleaned and freed from the adherence of any ash and placed in readiness for another analysis. Charcoal and wood may be analyzed in a similar manner, though it is rarely that such examinations are of value to central station practice.

The selection of the sample for analysis is a matter requiring more care and skill than the assay itself. Where coal is purchased in large quantities, by the carload or shipload, there should be selected from each consignment a sample of not less than two or three hundred pounds. This should be obtained by carefully shoveling over the shipment, if by vessel, or by selecting from a number of carloads the desired quantity. Particular pains should be exercised in obtaining this sample to see that all parts of the shipment are fully and justly represented. The whole sample should then be crushed until it is uniformly reduced in size to pass a quarter-inch screen. The sample should then be very carefully shoveled and mixed, so that all parts may be

thoroughly incorporated, giving a fair average representation, and should then be subdivided by successive quarterings until it is reduced in weight to about five pounds. The quartering is accomplished by the well-known mining method of "quartering," and consists in pouring the sample into a large tin funnel containing four divisions, made by a couple of sheets of tin placed along the diameter of the funnel at right angles to each other. The whole sample is poured into the funnel, and by retaining only the portion that collects in one of the divisions, three-quarters of the sample are rejected. By successive repetition of this process the bulk may be reduced to any desired fraction of the original amount, preserving at the same time a representative average. After being quartered down to about five pounds, the quartering should be carefully pulverized to a fine powder and then requartered until it is reduced to a quarter of a pound. It should then be pulverized in the agate mortar to an impalpable powder, from which the final assay sample is selected. Too much emphasis cannot be laid upon the care necessary in the selection of the sample, in order to get one which will fairly and justly represent the average character of the fuel. Particularly in the case of coal, the parts which are richer in carbon are more friable and brittle than those which contain slate or other gangue, and in the quartering an equal amount of fines must be evenly distributed throughout the quartering funnel. It is probable that the fear of inaccuracy in sampling has led coal venders in the past to offer the most strenuous opposition to the sale of fuel on analytical tests, though it is the fairest and most equitable basis both for buyer and seller.

All forms of solid fuel may, as outlined, be subjected with a small outlay of time and expense, to a proximate analysis, the information returned proving a guide of inestimable value in the economical management of a combustion plant. Liquid and gaseous fuel cannot be so easily tested, nor can the ultimate fuel elements in any form of combustible be readily ascertained. To make an ultimate analysis, determining all of the elementary fuel constituents of either solid, liquid or gaseous fuel, is a matter involving laboratory appliances and chemical skill that would transcend all but the largest and most important stations. Work of this class requires the highest technical and chemical manipulations, and involves so large an amount of apparatus and time,

that investigations of this kind should preferably be referred to a regular chemical laboratory.

The calorimetric method presents the inestimable advantages that by its means the net calorific power of any combustible may be immediately determined with an instrument that is utterly unaffected by any possible variation in the molecular constitution of the fuel under consideration, and that all forms of fuel, whether solid, liquid or gaseous, may be tested with equal facility. The rapidity with which determinations may be effected and the accuracy attainable are all so great as to make it the most effective means of ascertaining calorific power. The apparatus necessary is a chemical balance capable of weighing to a single milligramme, a calorimeter, a battery and tank of compressed oxygen, platinum crucible, water bath and Bunsen burner. The expense of the necessary apparatus stands as follows:

TABLE No. 68. EXPENSE OF APPARATUS FOR CALORIMETER TESTS

Balance	$ 25.00 to $50.00
Calorimeter	100.00
Agate mortar	5.00
Water bath	2.50
Bunsen burner and tubing	2.50
Total	$135.00 to $160.00

No mention is here made of the expense of the oxygen tank, as the necessary supply of oxygen may be readily obtained, compressed for use in the proper tank, from any of the many calcium light companies, which are now to be found in all of the larger towns.

The principle upon which all calorimeter tests are made consists in burning the carefully weighed sample of fuel in a sealed chamber, submerged in a weighed quantity of water. The temperature of the water is carefully measured before and after the combustion of the fuel sample takes place, and the calorific power calculated from the rise in temperature, which takes place in the water which is so disposed around the combustion chamber as to absorb all the heat developed during the burning. Several forms of this apparatus have been devised, of which the following have been selected as the best representatives of the different types.

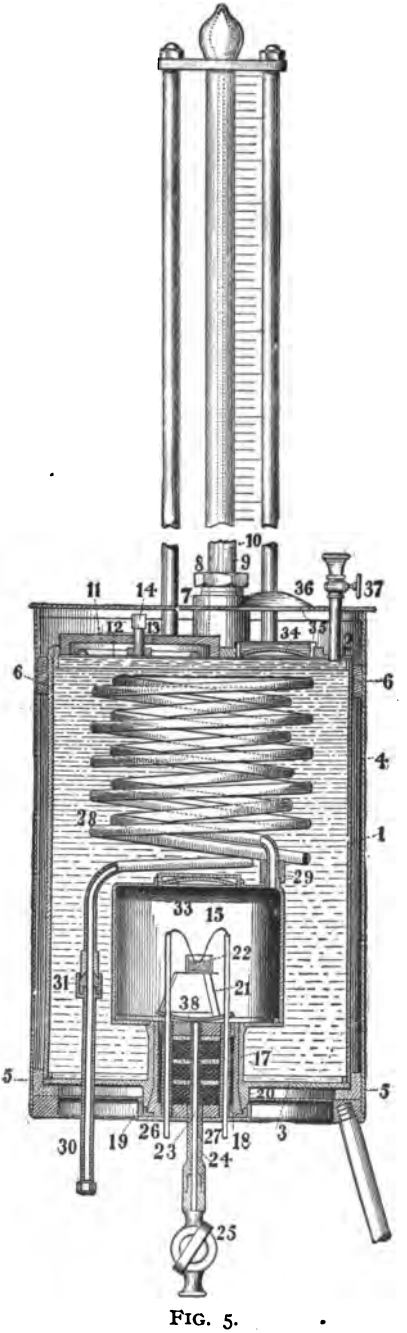
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FIG. 5.

The *Carpenter Calorimeter* is illustrated in Fig. 5 and consists of a combustion chamber (15) supplied with a removable bottom. This chamber is furnished with a tube (23) which may be connected by a flexible pipe with the oxygen tank and through which the necessary supply of oxygen for conducting the combustion is furnished to the chamber. The products of combustion are discharged through a spiral tube (28, 29, 31), terminating in a hose nipple (30), from which a rubber tube connection is made to a small chamber, supplied with a siphon gauge. By means of the siphon gauge the pressure of the gases may at any time be noted. The combustion chamber is surrounded by a larger vessel (1) which is filled with water, connected with open glass tube and attached scale (9 and 10). Above the water chamber is a diaphragm (12) which is used to adjust the zero level of the water in the open tube, by means of a screw (14), at any desired point. A glass bull's-eye, for observing the process of combustion, is inserted at (33) in the top of the combustion chamber, at (34) in the top of the water chamber and at (36) in the outer case. The whole instrument is then slipped into an outside case of polished nickel, carefully insulated to reduce radiation. The plug (17) which fits into the bottom of the combustion chamber carries a receptacle (22), into which the fuel sample for examination is placed. Two wires (26 and 27), extending through insulating bushings, are connected by a thin piece of platinum wire that dips into the dish (22). By means of these wires an electric current, passing through the platinum wire, is enabled to fire the charge. The plug forming the bottom of the combustion chamber is carefully insulated with asbestos, to prevent any losses by conduction. The apparatus is made sufficiently strong so that the combustion chamber may be subjected to considerable pressure, though practical use has demonstrated that about ten inches of water is amply sufficient for successful operation. The capacity of the instrument is about five pounds of water and is large enough for the consumption of two grammes of coal. When a sample of fuel is burned in the combustion chamber, the water in the calorimeter rises by expansion along the tube (9), indicating on the scale divisions placed adjacent the amount of heat that has been imparted to the instrument. The calorimeter is calibrated by burning in the combustion chamber carefully determined weights of carbon and noting

the rise of the water column along the scale. By this means it will be perceived that the operation of obtaining calorific power is exceedingly easy, consisting simply in introducing the weighed sample in the combustion chamber, supplying the necessary oxygen for burning and reading the height of the water column after the combustion is complete. To use the calorimeter the following directions given by the manufacturers should be carefully observed :

1. Select an accurate sample by a system of quartering, which shall commence with a very great amount and terminate with a very small fraction of a pound.

2. Reduce to powder by grinding in a mortar, sufficient for several assays.

3. Introduce the sample into a small weighed porcelain or asbestos cup, and weigh accurately.

4. Introduce the cup and sample into the calorimeter; (*a*) start the oxygen gas flowing; (*b*) fire the charge, which should be done by pressing on a key, closing a battery current through the platinum wire; (*c*) at instant coal is lighted, throw off the current and note the reading of the scale. By noting this, after firing, the correction for heat from electric wire is made by simple subtraction. Keep the pin hole open during combustion.

5. Watch the combustion, which will usually require about ten minutes for each gramme of coal, and when completed, note the scale reading. The water on the scale will rise about fifteen inches for the amount of coal usually burned.

6. To correct for radiation, note the amount of water in the column that has fallen for the same time as required for combustion; add this to the former reading to get the total number of heat units.

7. Divide the value as shown on the scale by the weight in pounds of the sample burned. The result will be the value in B. T. U. of one pound of coal.

8. Remove the dish in which the combustion took place, weigh it carefully with and without contents. If the combustion has been perfect, the difference of these weights gives the ash. Wipe combustion chamber dry for another determination.

9. To prepare for another determination, remove the calorimeter from the outside case and immerse in cold water, care being taken to prevent any water entering the oxygen tubes or combustion chamber. This method is preferable to emptying the calorimeter and adding fresh water each time, since the air, which is always present in water, will affect the results, and is a difficult element to remove. The operation of cooling takes but a few minutes, and is easily performed.

10. In order that the instrument may give accurate values, it is necessary that all air be removed from the water, and that the oxygen be supplied at a constant pressure. The pressure with which the instrument was calibrated is given with the calibration curve, and if any other pressure is used a new calibration should be made.

11. Do not attempt to use the calorimeter in a room whose temperature is above 80° Fahr., as the calorimeter should always be warmer than the air of the room.

For the practical examination of solid and liquid fuel the Carpenter calorimeter leaves little to be desired in respect to rapidity, simplicity and ease of manipulation. From a scientific standpoint, the thermometric accuracy and reliability of the indicating water column may be challenged, though, doubtless, the probability of errors in sampling are likely to be far greater. It is also questionable whether the combustion chamber is strong enough to be well adapted to gas tests.

Another form of calorimeter free from these objections is the bomb calorimeter, which has been brought to great perfection by M. Mahler.*

The bomb calorimeter resembles the Carpenter calorimeter to a notable extent, with the exception that the combustion chamber is made of steel and is strong enough to stand a pressure of 100 atmospheres or more, and the temperature measurements are made with a delicate thermometer. The general arrangement of analytical apparatus is shown in Fig. 6, while details of the combustion chamber are indicated in Fig. 7.

From Fig. 6, it will be perceived that the apparatus consists of an internal combustion chamber *B*, surrounded by a vessel containing a weighed amount of water. The water is protected from radiation by being placed in a carefully insulated chamber *A*, while a delicate thermometer *T*, placed in the water, serves to measure the temperature of the liquid before and after combustion has taken place; a stirring apparatus (*s*), manipulated by the operator, serving to bring all parts of the water to a uniform temperature. The combustion chamber is shown in section in Fig. 7, and consists of a strong steel vessel carefully enameled on the inside, supplied with a screw cap to close the opening provided for the introduction of the test samples. Through the cap two insulated wires extend, serving to convey to the sample the necessary electrical current for firing the charge. The cap of the combustion chamber is further supplied with a heavy metal valve to which the pipe from the oxygen tank may be attached. The operation of using this calorimeter is precisely the same as that already described, in so far as preparation and introduction of the

* See *Bulletin De La Societe D'Encouragement Pour L'Industrie Nationale*, June, 1892, p. 317.

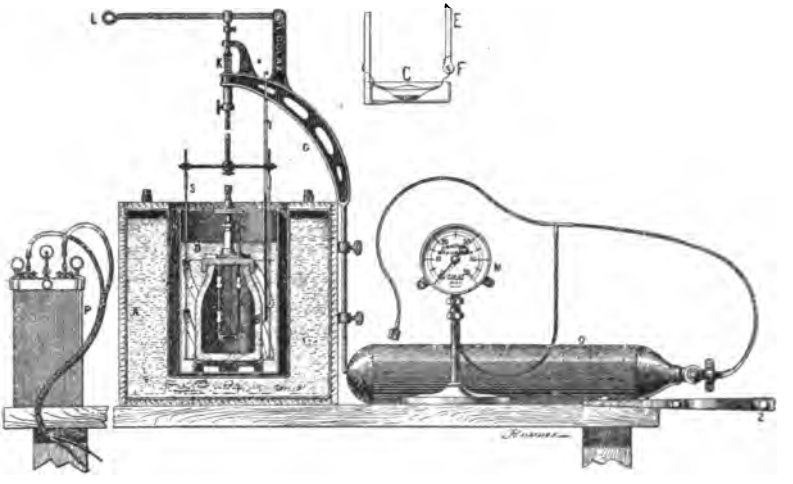

FIG. 6.

sample is concerned. After this is in position, the combustion chamber is connected to oxygen tank (*o*) and oxygen allowed to flow until a pressure of about twenty-five atmospheres is attained. The supply of oxygen is then shut off and electric current momentarily applied, which suffices to fire the charge, which, in an atmosphere of compressed oxygen, is immediately and explosively burned. The thermometer attached to the calorimeter is read just previous to firing of the charge, and then successive thermometer readings are made, while the water is carefully stirred until the thermometer ceases to rise, showing that the maximum temperature has been reached. From the known volumes of water and the equivalent specific heat of instrument, with the difference in temperature before and after combustion, it is easy to calculate the calorific power of the sample. The whole operation, exclusive of the preparation of the samples, does not require more than fifteen to twenty minutes. Considering the ease with which calorimeter tests may be made, and the inexpensive character of the apparatus necessary, it is strange that so little attention has been paid to this department of central station economics. In a 500-horse-power station, a variation of 5 per

cent in the calorific power of the fuel means more than a thousand dollars in the profit account, enough to materially influence the showing of a small plant. It is doubtful whether any part of power production receives so little or is worthy of so much attention as the fuel supply.

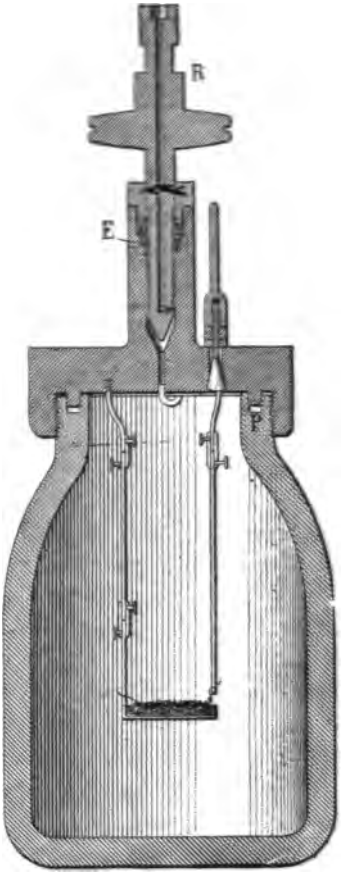

FIG. 7.

TELEPHONE CONDUITS AND SUBWAYS.

BY DR. V. WIETLISBACH, OF BERNE, SWITZERLAND.

Only underground cable installations are durable. In laying cables in the ground the character of the cable itself, as well as the local conditions, must be considered. Telephone cables are laid almost exclusively within cities, where the streets are already well filled with gas and water pipes, and where, in many places, high-tension current circuits for light and power purposes, steam-pipes, etc., abound. Moreover, the streets where the cables are laid are often torn up for building, street changes, paving, etc., and as the ground itself does not usually afford sufficient security against injury to the cables, they must be suitably protected otherwise. Against mechanical injury protection is comparatively simple, by drawing the cables into iron, wooden or other pipes. Protection against chemical action is more difficult. Nearly all cables now used in telephony are insulated with paper, which is hygroscopic, and from which moisture must be absolutely excluded in order to maintain the insulation. This is done by forming around the core a tight-fitting lead sheath, hermetically sealed to the air. Lead sheathing is applied also to cables with non-hygroscopic insulation, such as gutta-percha and rubber, to prevent the access of chemical agents, as acids, etc., which easily ruin them. The life of a cable is entirely determined by the durability of its lead sheath. Experience shows that ordinary lead pipes laid in the ground without further protection have been destroyed in five to ten years, especially in streets of cities, where the ground is saturated with all kinds of organic matter. From these organic substances are produced by fermentation and decomposition carbonic acid and organic acids which form salts with lead. Some of these acids, especially acetic acid, have a great affinity for lead, forming salts which are acted upon by hydrocarbons, and in moist places are readily transformed into

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carbonates. This transformation into carbonate again frees the acid, which may attack a fresh portion of lead. In this manner a small amount of acid may in time cause great destruction of the lead sheath. When cables are laid in the ground the conditions are most favorable for starting such chemical action.

The pipes and conduits containing the cables are ordinarily full of gaseous hydrocarbons from illuminating gas, and only the active principle, an organic acid, is needed to form the carbonate. This also is present under the pavement, where the ground is saturated with organic substances. The acids are mobile and exist in solution, and they will penetrate wherever the conduits are not completely water-tight. Sometimes acids are formed from the conduit itself, if of wood and not entirely freed from sap by impregnation. Decay thus sets in and destroys the conduits as well as the cable. Clean sand and gravel, both of which allow an easy passage to water and gas, do not offer the conditions essential for the destruction of the lead; so the leaden water pipes laid by the Romans "In Monte Palatino" have lasted through millenniums.

Cables may be laid in the ground in many different ways, but all the methods so far presented may be classified under three heads:

1. Simple construction, where either bare or armored lead cables or insulated wires cabled are laid directly in the ground.

2. Subway construction, where walled passages are built under the surface of the street, large enough for men to walk through and to permit of hanging the cables along the walls or laying them on the floor.

3. Conduit or duct construction, where manholes are built in the streets and connected by pipe ducts, through which the cable can be drawn in and out.

Each of these three systems will be treated in order.

Simple Construction. The easiest way is to open the street throughout where the cable is to be laid, then to reel off the cable into the trench and fill it in again. As there are usually in the street a good many other conduits besides those for telephone cables, such as gas and water pipes, electric light circuits, etc., and as digging is frequent for repairs of these various pipes, or for paving, the cables must be protected against mechanical injury. For a single small cable it is sufficient to let the cable

take care of itself by giving it an armor of iron wire or band iron. With a number of cables it is preferable to put the protection around the bunch instead of on each one. In this case a trough is built in the cable trench. A very economical conduit may be made of channel iron, if suitable shapes are obtainable. First a channel iron is laid in the trench, and the ground tamped around it; then the cables are reeled off into it and covered up by the second channel iron, clamped to the first one by galvanized iron wires or hooks. Channel iron is manufactured in certain sizes only, and owing to its form requires a wide trench. Therefore, if space in the street is limited and many cables are to be laid, this system is not practicable, and another kind of trough must be used, specially designed for the purpose. Fig. 216 illustrates the cross section of a cast-iron conduit as used in the underground system at Hamburg. It consists of a series of troughs and covers of cast iron, 26 to 40 cm. (10 to 16 inches) wide in the clear, and 26 cm. (10 inches) high, the covers being on the average 60 cm. (2 feet) below the street level. Bends in the cable route can be made down to 30 m. (100 feet) radius with the use of the straight troughs. For bends of a shorter radius, curved sections of 1 m. and 2 m. (40 and 80 inches) radius, and 1 m. (40 inches) length were designed. At points where lines branch off, the junction boxes shown in Fig. 217 are inserted. A very cheap conduit can be made of clay pipes in various forms, or the cable may be laid in the ground in a bed of sand and then covered with bricks placed close together, but not cemented. Another method (Dow's) is to lay the cables on a cushion of 2½ inches of dry mortar (native cement one part and sharp sand four parts, screened together), while over them is placed three or four inches of the

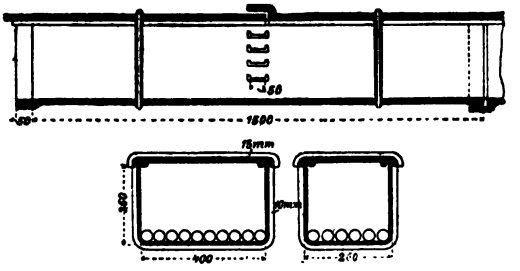


FIG. 216.

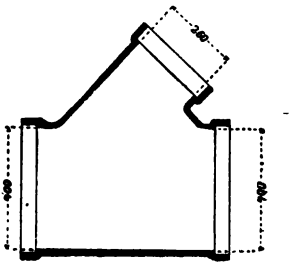


FIG. 217.

same mortar wet, from which the cushion absorbs sufficient moisture to set as hard as the top layer.

The principal disadvantage of the simple conduit is the inaccessibility of cables when once laid. They can be got at only by tearing up the street, and repeated street excavations are a great nuisance, as on the one hand new pavements, such as wood or asphalt, are very costly, and the street suffers through constant tearing up and repairing, for a long time elapses before the newly paved street returns to its normal condition. Furthermore, traffic is disturbed, and finally many inconveniences arise from other pipes, such as gas, water or lighting mains, which cross the cable route and may have to be cut or displaced. In order to avoid the reopening of the street for new cables a large number of spare ones must be laid at the start, and may lie idle for years — a doubtful policy, for with the rapid development of telephony future requirements cannot be gauged accurately, and the cables laid now may not fill the demand after a few years. Besides, cable manufacture is constantly progressing, and by the time the reserve cables are needed, better and cheaper cables may be obtainable. The maintenance of the cables becomes more difficult also. A cable is liable to damage, but its inaccessibility will render repairs impossible, thus rendering it useless, while otherwise it might have been restored to service at slight expense.

In choosing an underground conduit, the locality to be served is an important factor to consider in estimating the cost. For instance, in a purely residence street a single cable may suffice for many years. An expensive conduit for this one cable would not pay, for interest and depreciation on the conduit would in a very few years amount to more than the cost of a new cable. In such a case, it would be more economical to lay the cable in the ground, or to build a very cheap form of conduit and to lay a new cable if the old one should be injured or in time prove insufficient.

Of the two main factors of a telephone cable plant — the cable and the conduit — experience has definitely settled upon a uniform type of cable, now in use the world over. Details may vary — such as the size and the number of the conductors, the thickness and diameter of the lead sheath, etc. — but the general type is everywhere substantially the same: paper-covered copper wires twisted in pairs, cabled and covered with lead pipe.

This general agreement is the result of the fact that no other type approaches the electrical qualities of the paper cable, especially in the vital one of low capacity, while at the same time no other cable is so cheap.

As to conduits, however, no such unanimity of practice has been or is likely to be obtained. The problem is mechanical, not electrical, and varying local conditions must be met in various ways. Still some general principles may be noted, as commonly agreed upon.

The cheapest and most convenient conduit is undoubtedly the simple walled trench with removable cover, the cables being run directly into it off the reel as it is wheeled through the street. But this is very rarely feasible, and we are usually limited to conduits with ducts, having reason to be very grateful if space can be found for them in the already crowded streets.

Some of the features generally agreed upon as desiderata in such conduits are :

1. Manholes at convenient intervals for drawing in and splicing, and for distribution overhead.

2. Perfect alignment between manholes; or curves of very long radius where unavoidable.

3. A separate duct for each cable.

4. A conduit material practically indestructible in the worst soil encountered in city streets, and capable of withstanding the chance strokes of laborers' picks and crowbars.

5. Construction strong enough to resist the strain of the heavy loads of street traffic. This involves good foundations, to maintain the alignment of the conduit.

The strongest and most durable of all conduits is unquestionably the cast-iron pipe, imbedded in cement, but it is also the most expensive. The sheet-iron pipe with cement lining is cheaper and nearly as good. Of other good conduits the most economical are, for America, the earthenware or the creosoted wood pipe conduit, and for Europe, the cement block conduit. But it is not always practicable to apply the system preferred from an engineering point of view, and lack of available space in the streets or failure to come to an agreement with city authorities may compel the use of a system that falls far short of fulfilling the desiderata. We may be forced, e. g., to heap the cables together in a single large iron pipe, as in Germany and Switzerland, or

even to lay them at the bottom of a trench and fill up with earth again, not only rendering them inaccessible, but also preventing subsequent increase.

It is a question of laying the cables in *some* way, and when the best mode is impracticable we must take up with what we can get.

Subways.—To obviate these difficulties, a subway underneath the street is often used, capable of holding other mains beside the electric cables and spacious enough to afford the workmen free passage. The Paris sewers are cited as the ideal in this direction. They contain the gas and water pipes and carry along the walls the telephone and telegraph lines, while the electric light mains have separate conduits. Fig. 218 shows a cross section of a Paris sewer. The average height is 2 m. (80 inches) and width 1 m. (40 inches), the main sewers or "collectors" being still larger. The small cables, one pair to seven pairs, are suspended on iron hangers at the sides. Each hanger supports 3 times 17 of the old seven-pair cables, or a total of 51 cables with 357 circuits or 714 wires. The larger cables are placed in portable sheet-iron boxes, supported by iron hangers on the sides of the sewers; each containing four 50-pair cables or a corresponding number of cables of other sizes. These boxes are made in sections of 1 m. in length and consist of two pieces of 2 mm. sheet iron, the box and its cover. Ordinarily the cables are drawn into the sewer through manholes; occasionally the whole cable drum can be introduced and the cable reeled off by wheeling the drum, which is mounted on a small cart, along the tunnel. Wherever subways of this sort already exist for other purposes, they may be used advantageously for telephone cables, but to build them specially for this purpose would, in general, be far too costly.

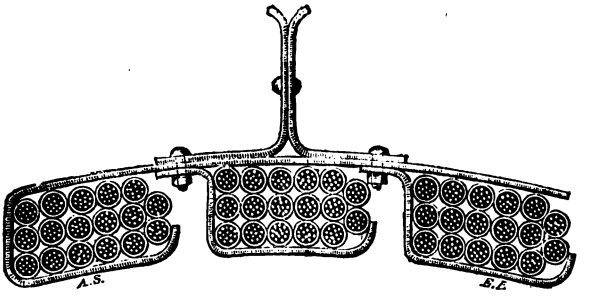
Conduits.—These have proved the most successful, and the fundamental principles of their construction embody the following features:

A perfect alignment as far as possible; mechanical strength and adaptability to the needs of laying and handling the cables; durability and freedom from the possibility of chemical action.

Usually a number of pipes are laid in the ground together, each for a single cable. These pipes end in manholes, through which the cables can be drawn in and out as occasion requires. All that is necessary is to put in a sufficient number of pipes at

the start; cables can then be drawn in as required. A damaged cable can easily be pulled out, repaired and relaid.

Cast-iron pipes form a good conduit material, being obtainable in all sizes. They possess sufficient mechanical strength, and can be easily and quickly laid; the joints can be made absolutely tight and comparatively small curves may be turned. Cast-iron pipes often have sharp points on the inside owing to defective molding, necessitating careful reaming out before pulling in lead-covered cables. Wrought-iron pipes are better, being smoother on the inside. The pipes are placed in the open trench on a bed of concrete, and the same material is filled in, around and over them. The pipes should not deviate unnecessarily from a straight line, either horizontally or vertically, in order to facilitate the



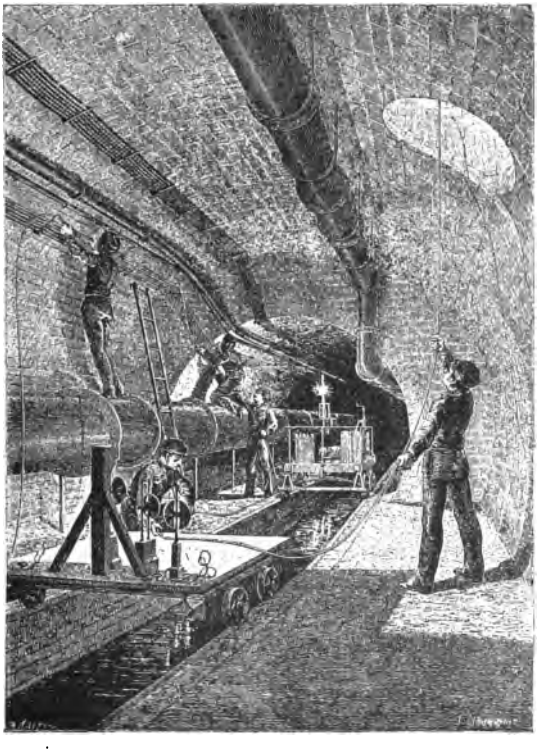


FIG. 218.

[illegible]

drawing in of the cables. Any indispensable deviation should be brought as close to the manhole as possible. The pipes should be placed so that their female couplings are on the side toward the exchange. The cables are drawn in toward the exchange hence pass over the edges of the pipe ends inserted into the couplings. This precaution becomes important on curves, where the projection formed by the sharp edge of the following pipe, which is inserted into the coupling of the preceding one, would make trouble if the cable were drawn against that edge.

Fig. 216.

[illegible] are protected from rust by asphalt or tar, but the [illegible] must be kept as smooth and even as possible. [illegible] made tight in the ordinary manner with hemp and [illegible]

[illegible] conduits are often made of other materials, as, [illegible] the cables are drawn into pipes of the required [illegible] of No. [illegible] sheet iron only [illegible] inch thick, and [illegible] protection.

[illegible] called the Vieckof conduit, uses rectangular [illegible] with holes to suit the cable. [illegible] into conduit of any required size and [illegible] These conduits seem to be pretty durable [illegible] risk that the decay of an imperfectly [illegible] destroys not only the conduit but also the [illegible] upon the lead by acetic acid from [illegible] It should be said, however, that experiments [illegible] points in the creosoted wood conduit, [illegible] creosoter yet devised. Microscopic [illegible] change if properly creosoted

blocks after thirteen years in the ground. Fig. 220 shows sectional view of the tubing; Fig. 221, method of laying; and Fig. 222, the tubing as it enters into the manhole.

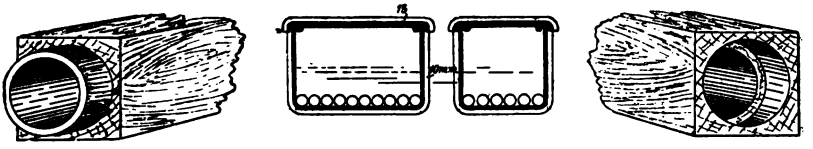


FIG. 220.

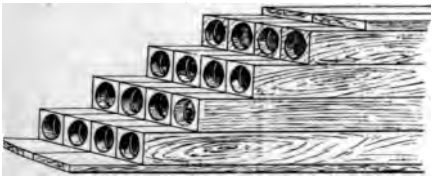


FIG. 221.

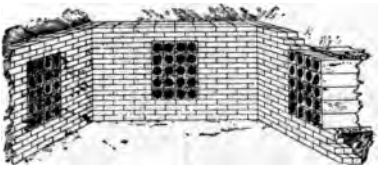


FIG. 222.

This wooden tubing is made in lengths of eight feet, and if accurately bored and then reamed the joints can be centered true and a smooth, continuous duct secured, into which cables can be drawn without encountering offsets or projections. When leaving the machine the tube varies in external diameter from 3 inches to 5 inches square, according to the size ordered, while the internal diameter of the duct is 1½ inches smaller. The length of the tenon and the depth of the mortise in all the sizes of tubing are 1½ inches each, which should insure a tight and stable joint. The process of creosoting shrinks the wood slightly, and a cross-section of the finished product shows slightly decreased measurements. In applying the process the tubes are loaded onto small cars and pushed within a huge steel cylinder and submitted to a steaming process under a pressure of eighty pounds per square inch, that opens all the pores of the wood. The steam is then withdrawn, and hot creosote pumped into the cylinder and forced into the pores of the tubing under a pressure of one hundred pounds per square inch, the exact amount the wood shall absorb having been previously determined. Thirty-six pounds of creosote oil are required to saturate one cubic foot of wood, but specifications usually only call for a treatment of from 8 to 20 pounds of oil for each cubic foot of tubing treated.

The cost of creosoted wood conduits in the Michigan mills [illegible] cents per linear foot. One-tenth of a cent is [illegible] the cost of placing the conduit in the trench. But the [illegible] of digging the trench varies with the locality, the character of the soil, and the material to be removed. Trenching and refilling for the necessary depths have been contracted for as low as [illegible] cents per foot. When more than one duct is laid, it is the usual practice to place a creosoted plank of from 1 inch to 2 inches in thickness in the bottom of the trench to afford a level surface for the conduit to rest on, and a similar plank on top to protect the conduit from the effects of tools in the hands of workmen making subsequent excavations, improvements or changes. Special forms of tiling can be supplied for curves, or short pieces can be used either in alignment or on grades.

Many other forms of conduit have been devised, some of them composed of earthenware or cement blocks fitted together.

In Chicago many conduits have been built of terra cotta ducts of a rectangular section, laid in layers. Each duct has a horizontal partition in the center, the cables being drawn into the compartments thus formed.

The space on each side is [illegible] by [illegible] inches, and holds four 50-pair cables. The upper row contains a number of T's by which cables or single wires branch off, these openings being filled with cement or other mixture until needed for use. To make a junction the hole is opened and a terra cotta pipe, ordinarily of 3 inches diameter, is inserted and cemented on. The house connection is effected through pipes of the same diameter. Through the wall of the house an iron pipe is driven, and in the inside of the basement a trap filled with oil is attached to keep the gases in the duct from entering the house. The wires enter the basement through the same pipe and the oil. A similar conduit is used in Stuttgart.

Of more recent date are separate terra cotta ducts. They are 4⅝ inches square on the outside, having their edges rounded off; the round hole inside is just big enough to allow the cable to pass easily. They are built in lengths of from 18 inches to 2 feet. To construct a conduit the trench is lined with concrete and the ducts laid in layers, one line of duct being laid first through the center of the trench to secure alignment. The tiles are cemented together and kept in correct location by mandrels,

which are pulled along as the work progresses. To insure good joints the tiles are staggered just like bricks in a wall. At junctions tiles are cemented on at right angles. This kind of conduit is somewhat more expensive than the large tile one, but has the advantage of providing a separate pipe for each cable. (Fig. 223.)

McRoy's vitrified terra cotta conduit appears to be an indestructible and inexpensive form of conduit that has been adopted in several American cities. The shale used in its construction is

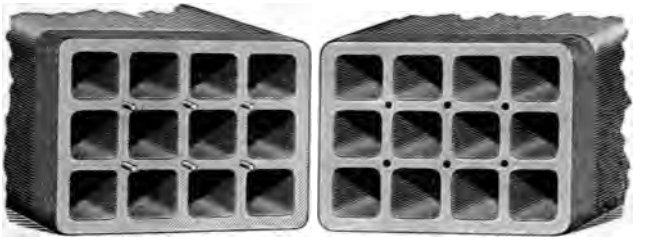


FIG. 223.

thoroughly ground and thus rendered free from rough particles, and by reason of the shrinkage that occurs in the ovens a perfectly dense mass is secured that renders the conduit nonporous. It is vitrified throughout, and all surfaces, both interior and exterior, glazed as an extra precaution against moisture. The conduit is manufactured in multiple duct form of any number or cable capacity, and in section lengths of 6 feet, in widths of 8½ and 13 inches, and with two, three, four and six ducts, or larger if desired. (Fig. 224.) In cross-section dimensions the outer walls are ¾ inch with partitions ⅝ inch thick, and duct openings 3¼ by 3¼ inches square, with rounded corners. There are two forms of joints used. One known as the cement joint, the other as the asphalt burlap joint. In making the cement joint the iron dowel pins are first placed in abutting joints, the mandrel is pushed through each opening to square the joints, and then tar paper is wrapped about the joint to prevent any mortar from finding its way into the ducts, and serve as an obstruction to the indrawing of cables. In making the asphalt joint after applying the iron dowel pins and the mandrel, burlap cut in strips eight inches wide and of sufficient length to wind five times around the pipe is dipped in a kettle of boiling asphalt

250° Fahr.) rolled on an iron roller and then wrapped around the joint. When cold this forms a very hard, air-tight and waterproof joint. This form of conduit is always placed on a level concrete foundation and covered with a layer of concrete to afford protection from rough usage. The machinery for making this conduit is patented.

At Stockholm, Axel Hultman has introduced a system of cement pipes. The blocks are traversed by holes for the cables, and are usually 1 m. (40 inches) long, the smaller blocks for six to ten cables being 1½ m. long. At the joints the blocks rest on cement seats. The distance between manholes averages

FIG. 224.

120 m. (400 feet), the cable sections reaching only from manhole to manhole. The cables used have from one hundred to two hundred pairs of conductors. The blocks are provided on the outside with three deep grooves to receive iron bars, to keep them in line. Friction between cables and pipes during drawing in is avoided by an application of grease. This system has given

satisfactory results and has been extended to various other towns in Sweden, as well as to Christiania and Copenhagen.

When several cables are laid in a single duct, they will not usually form a straight line but a wavy one, and it is desirable that they should lie straight so as to utilize all the space. For this purpose a packer is drawn through to force the cables into their proper positions. Such packers vary according to the form and size of the space left free in the duct.

The cables themselves should have a surface as smooth as possible. Lead cables are best drawn in without taping or further covering of any sort. Small cables, which may be armored, if they have to be drawn through great distances, should be wound with band iron—not wires—polished outside. The cables should be greased with tallow or talc.

Cable laying in New York has encountered a peculiar obstacle in the high temperature produced by the pipes for steam distribution, amounting sometimes to from 150° to 200° Fahr. (66° to 95° Cent.). The ducts have therefore been ventilated by way of the manholes so as to prevent heating the cables and at the same time to hinder gas from filling the ducts, thus avoiding explosions. Though all parts of the conduits are built as air and water tight as possible, experience shows that illuminating gas penetrates in a short time, rendering work in the manholes dangerous, and producing explosive mixtures of gas and air. The first attempt at ventilation consisted in placing blowers at different points on the route. But the more cables were laid, the more difficult became the ventilation, until now an extra ventilating pipe six inches in diameter is laid over the conduit, with openings into each manhole, increasing in size with the distance from the blower. Through these openings air is forced into the conduit, but no draft is intended, for that would only favor the escape of gas from the gas mains and such foul air into the conduit.

Where ventilation is insufficient there are frequent explosions of the mixture of gas and air which collects in the manholes. Though by these explosions the cables are not at all, or only very little damaged, the covers are often blown off, disturbing street traffic and injuring the manholes. The immediate causes of such explosions are not yet clear. There are probably various causes. The most natural explanation is the electric current

itself, especially where electric light cables are carried in the same conduit. A fault may cause one part of the line to overheat or sparks may jump from one line to another, readily causing an explosion. For this reason the conductors must be just as well insulated at the manholes as elsewhere, and all connections must be carefully made. The lead pipe should have good connection to earth everywhere so that no strong induction currents may be produced in the cables, but the induced electricity flow at once to ground.

Explosions have often happened, however, at times when it could be proved that there was no current on the line. The possible causes of explosion, given the explosive mixture of gas and air, are so numerous that absolute prevention is very difficult, if not impossible. The only sure way is to prevent the gases from collecting. Besides blowers this may be attained simply by leading pipes from the manholes into high chimneys on housetops, or up poles at the distributing points. We may use for this purpose the pipes in which cables branch off from the main route; only they must be of somewhat greater section so that the cables shall not fill them up entirely. The process of diffusion rapidly carries off the gases to the outside air.

The cable is usually carried in a single run from the exchange to the last manhole, when connections to the aërial lines are to be made. Splices are always made in the manholes.

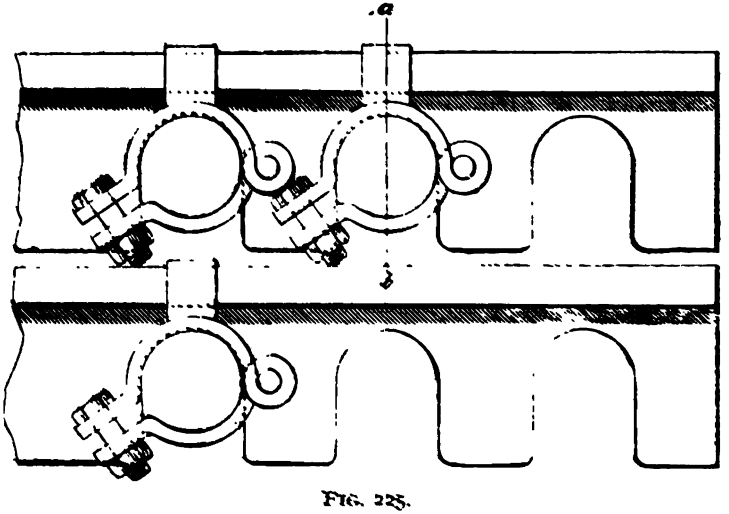


FIG. 225.

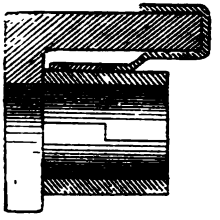


FIG. 226.

For connection to overhead lines either a house-top standard or a pole is selected. In Berlin the cables are brought up the rear of the house to the roof in fours or sixteens (in the latter case making 448 lines). As the cables are armored only four or five supports (every 3 or 4 m.) are necessary. These are iron clamps of the form shown in Fig. 225, screwed over the cables to angle irons, carried on iron supports. To hold the cables horizontally the clamps are also provided with hooks which engage in the upright flange of the angle iron. (Fig. 226.)

If the cables are intended to be run up a pole to connect with the aërial lines, it is advisable to use an iron pole on account of greater durability. The lightning rod may be fixed at the base. Good ventilation must be provided so as to keep the trough always dry. The bottom of it must be as air-tight as possible to prevent access of vapors from the ground, and airholes should be drilled in the upper part. The connection between lightning arresters and insulators is made with weatherproof wires, which may be twisted into a cable and drawn into a lead pipe run up one corner of the post. (Fig. 227.)

The insulating material of telephone cables being usually hygroscopic, it is of great importance to prevent moist air from coming in contact with it, during laying as well as afterward. The points of danger are the splices and the ends.

Ordinarily cables run from the exchange to the distributing point without branching off, so that at the splices it is only necessary to join two cables of the same number of wires. The single wires, after a careful cleaning, are twisted together and covered with a paper tube. The whole joint is then steeped in boiling paraffin and covered with a lead sleeve which is soldered to the pipe on both sides. An iron coupling in two halves is sometimes used with armored cables, being firmly bolted down over the cable at both sides. The coupling used in Berlin is shown in Fig. 228.

The filling with paraffin requires great care, in order to expel all moisture. It must be poured on slowly, keeping it continually at the boiling point. This filling becomes unnecessary where the dry-air process is used.

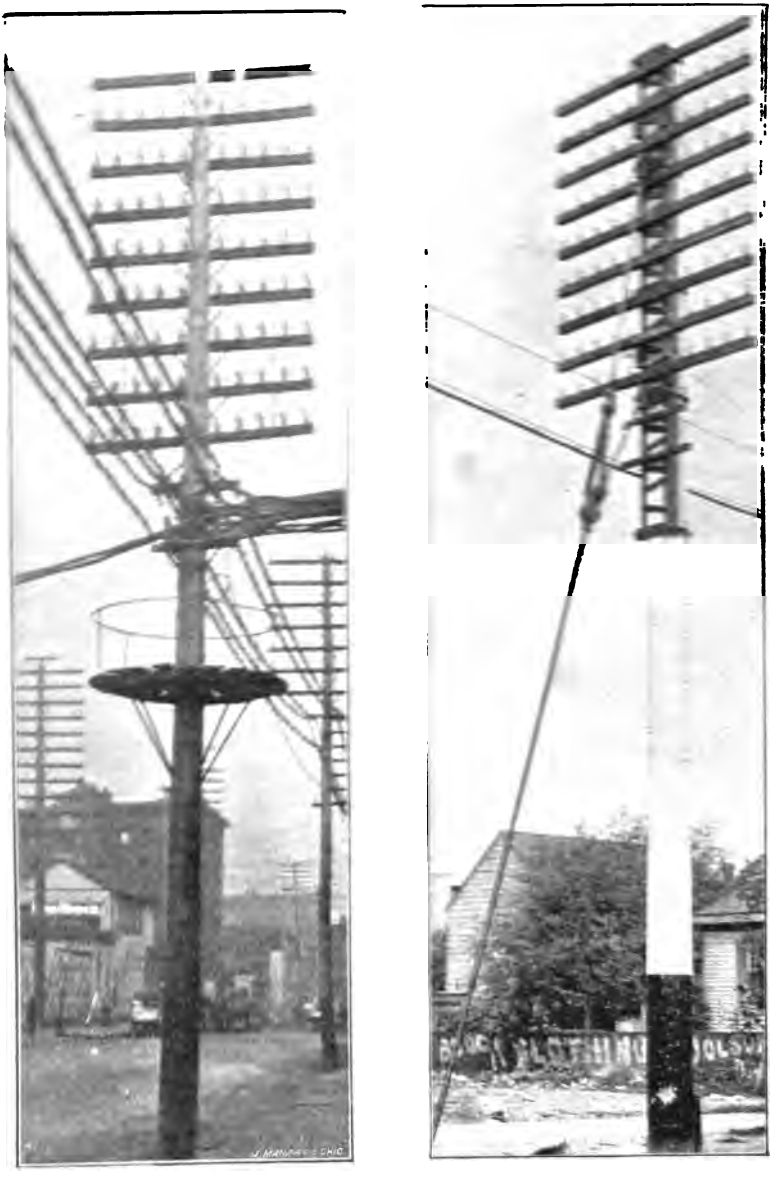


FIG. 227.

Sometimes a cable has to be branched off at some intermediate point. To this end an iron distributing box is often used, partitioned off into two chambers by a plate traversed by the required number of terminals. The cable arriving from one side enters the upper chamber, and each wire is soldered to a terminal. The continuing cables pass into the lower chamber, and their wires are soldered to the lower ends of the terminals. In this manner any wire of the entering cable may be connected to any wire of the continuing cables. The connections made, the box is heated to expel moisture and then made air-tight on both sides by covers fitted with rubber strips.

The cable ends must also be hermetically sealed, and for this purpose are usually fitted into a cast-iron box filled with insulating compound, out of which project the copper wires.

Fig. 229 shows the cable head used in Berlin. On top of the cast-iron funnel to which the cable is clamped is an ebonite plate drilled with as many holes as there are wires. A wire is drawn through each hole and brought to a terminal over the funnel, thence to lightning arrester and insulator.

Fig. 230 illustrates the cable head generally used with Patterson cables. It consists of a cast-iron box having a cover screwed on and made air-tight by means of rubber strips. The sides are fitted with terminals mounted in ebonite bushings. The cable enters at one end and the wires are clamped between the nuts of

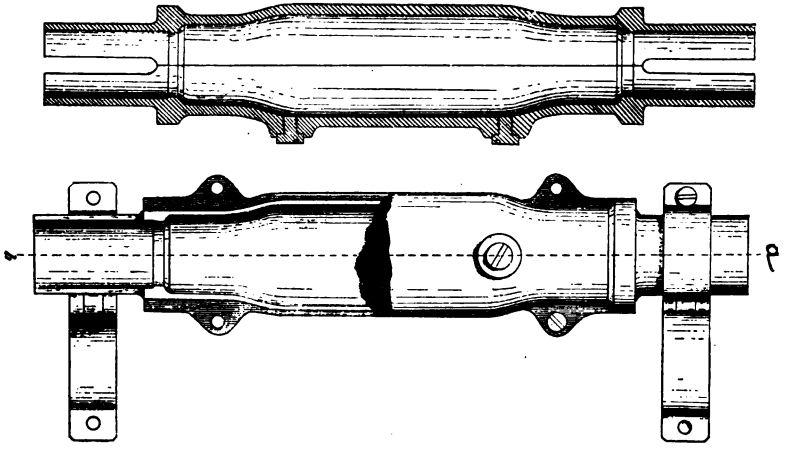


FIG. 228.

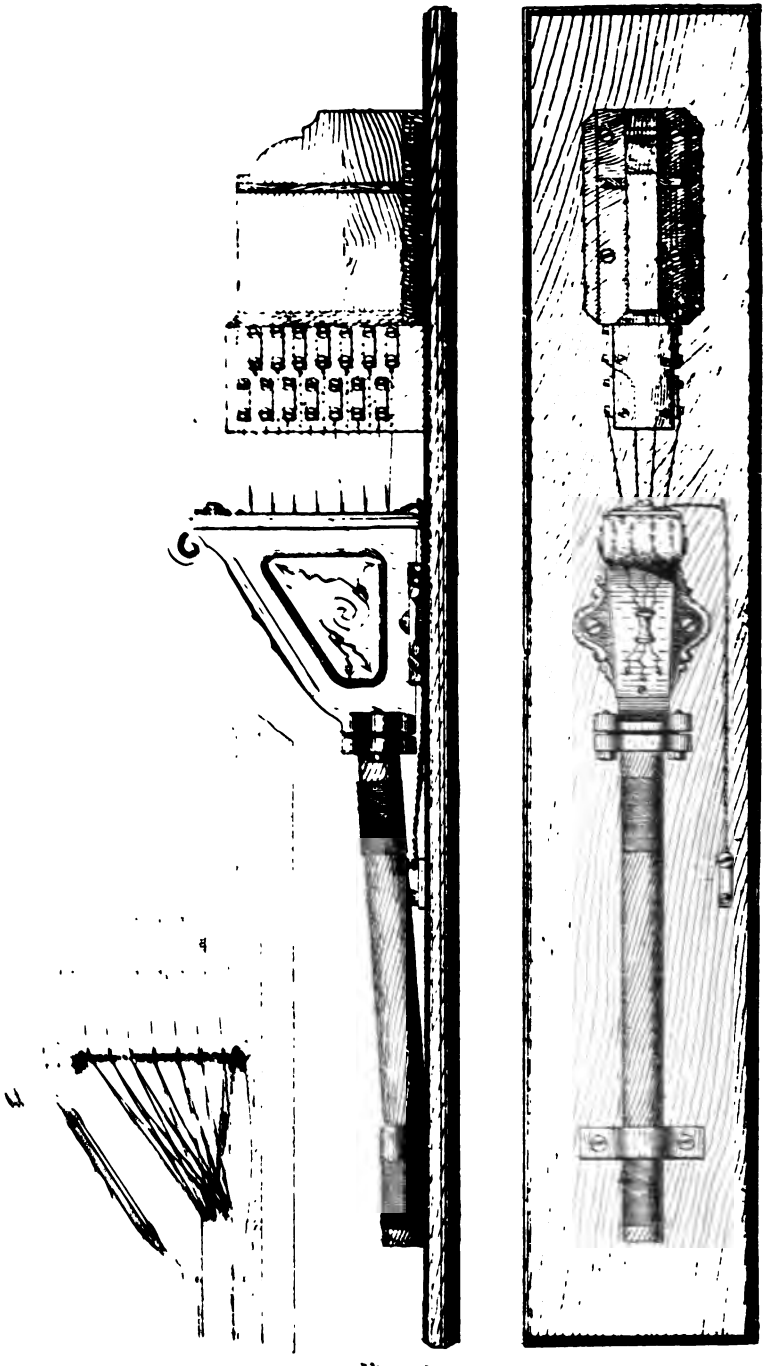


FIG. 229

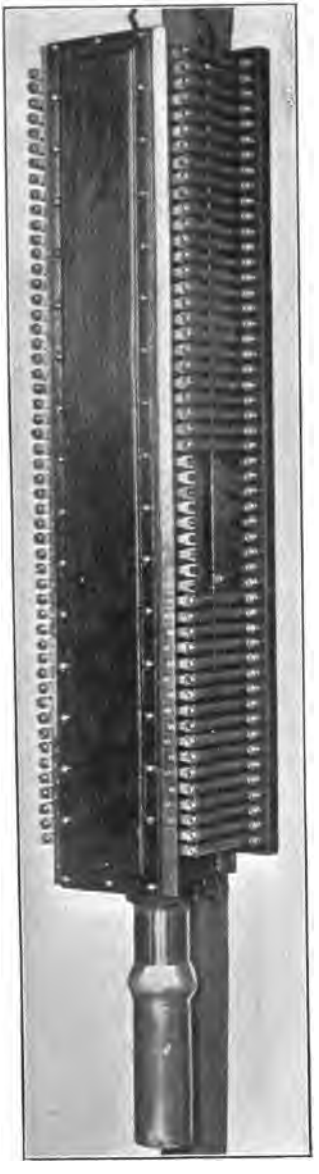


FIG. 230.

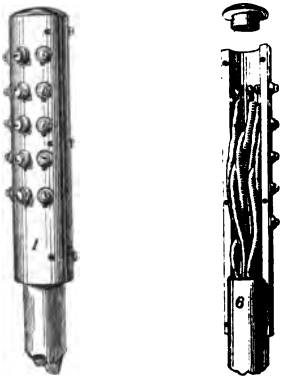


FIG. 231.

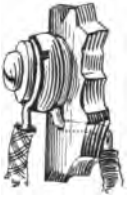
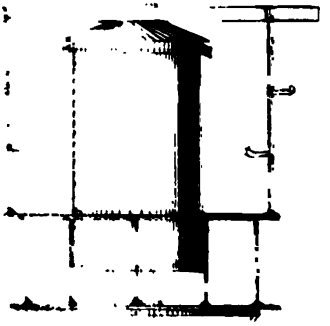


FIG. 232.

[illegible] filled with hot paraffin. The [illegible] the line or switch board [illegible] the exchange as well as on poles [illegible] between underground and aërial [illegible] terminal similar in shape to the [illegible] shown in Fig. 231. Where this terminal is filled with insulating material, a hard rubber cap is fitted on that renders it moisture-proof.

When the lines are short and built low, special lightning arresters are considered unnecessary, but long and exposed lines must have such protection. For connections on house tops the lightning arresters may be placed in the attic or the same arrangement may be used as in the exchange, but for pole connections the arresters are placed in an iron box on the pole. Fig. 233 shows a cable terminal pole recommended by the American cable committee. The cable terminal is a galvanized sheet-iron cylinder five feet in height and thirty inches in diameter. Below this cylindrical box is a platform or balcony upon which workmen can stand. Each side contains two doors, which afford easy access to the lightning arresters from all sides. The doors are made water-tight with rubber strips. Insulated wires are carried out of the box through pipes to the outside lines, and when the work is completed all openings are sealed with wax.



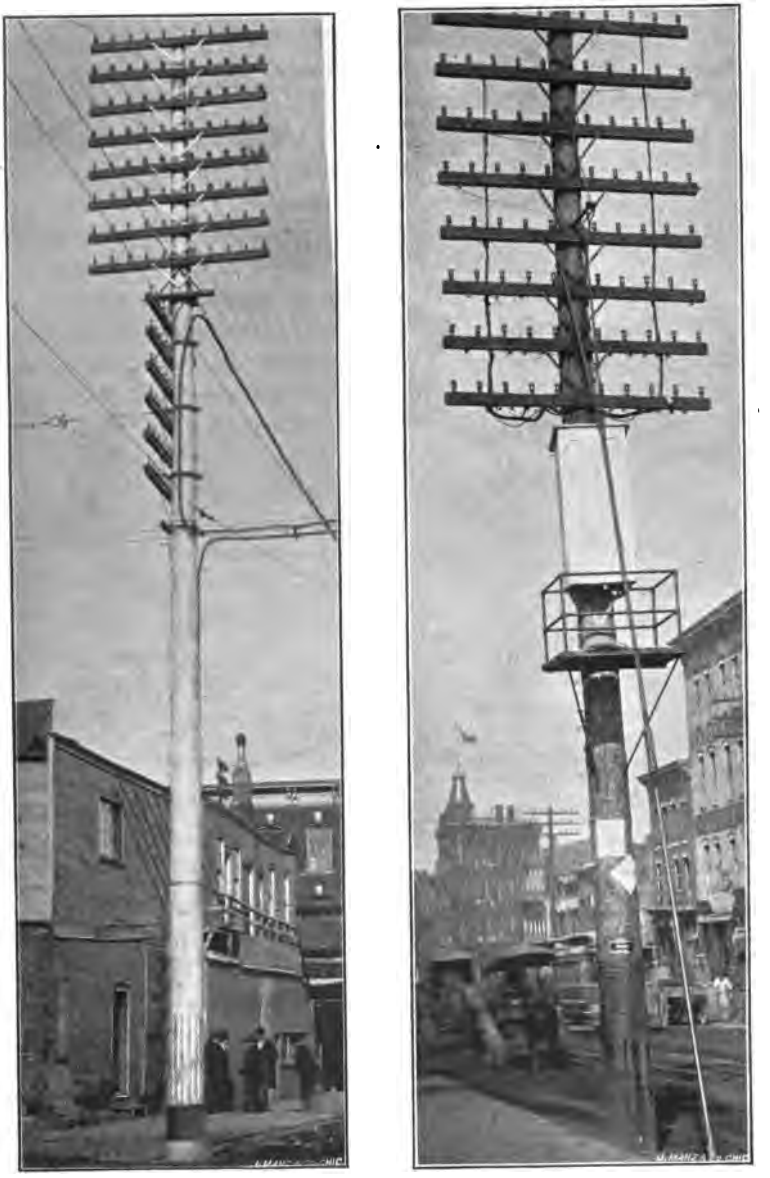


FIG. 234.

Wooden boxes are also used for this purpose. They are rectangular and have a double door in front over which is folded down the top, which has a hinged extension. A platform is attached to the pole below the box, which is fixed to the pole by iron bands. The roof is slanting to allow rain to drip off. When work is to be done on the cable head, the workman first lifts the extension of the top, which in its ordinary position entirely covers the front doors, then opens the doors which form a support for the extension, and thus makes for himself a roof to work under. (Fig. 234.)

Ordinarily cables do not extend to subscribers' offices, but connections are made overhead on poles or house-top standards to which the cable is carried. In some cases, however, it becomes necessary to make these connections underground. It is, of course, impracticable to open up the street for every connection,

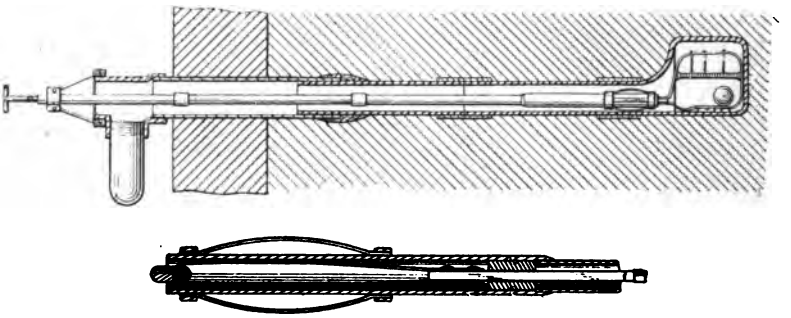


FIG. 235.

but once for all a cable intended for a whole block is drawn into a basement or some other suitable place and thence used as occasion demands. In an arrangement of this kind, of course, many wires may lie idle for years. To avoid this they proceed in Chicago in the following manner:

As mentioned elsewhere, the main line receives at certain intervals T-pipes for junctions. According to demand, a suitable number of connections are run to the basements of adjacent buildings either at the beginning or later on. Whenever a new connection is needed a new line is drawn through the pipe by the aid of a special tool, without interference with the street. The tool used is illustrated in Fig. 235; it consists of an iron

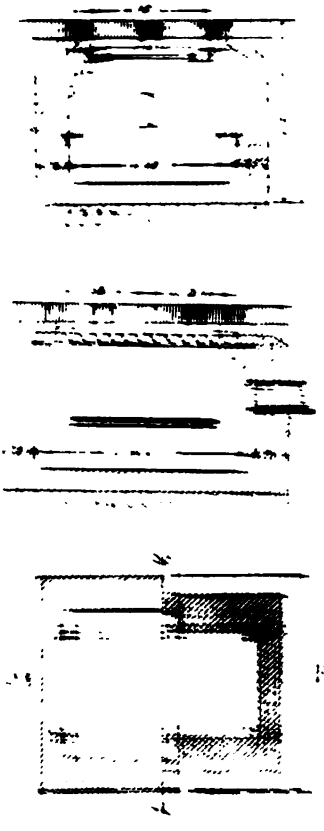
tube enlarged at the end, and carrying a movable rod with loop made of a steel band riveted to it. Tube and rod can be built up in sections screwed together to any length. For use the steel loop is drawn into the tube and the tool inserted in the junction pipe and lengthened by the requisite number of sections until the end carrying the loop reaches the main line. Then the loop is pushed out of the pipe by the rod and expands in the main duct, pushing aside the wires and small cables. Next a rod built up in sections is pushed through from the nearest manhole into the loop formed by the steel band until it reaches the next manhole, where the new wire is attached, and it is pulled back until the wire passes through the steel loop. Then the loop is drawn into the tube again by drawing back the inner rod, and the wire thus wedged in tight can be pulled into the basement. In this manner any number of wires may be drawn in, when the junction ducts are once laid, without opening the street. It is evident that only light flexible wires can be drawn in, such as the steel loop at the junctions is able to push aside.

All small cables or single wires which branch off between two manholes to houses or pole lines, are carried in the top layer of ducts, which only have T connections. All cables going direct from one manhole to the other are in the lower layers.

For drawing in the cables manholes must be provided at intervals. These are to be arranged so that the ducts between two manholes form a line as straight as possible. Manholes are located also at all crossings and junctions. The distance depends on the weight of the cable. For heavy cables (100 pairs and over) it is desirable to have a manhole every 100 to 150 m. (300 to 500 feet). Lighter cables may be pulled through in somewhat greater lengths, but the limit is soon set by the mechanical strength of the cable. The manhole must be large enough to allow men to work in it comfortably, and its form must permit the best disposition of cables and splices with a view of laying, splicing and accessibility for repairs.

The depth depends also on the location of the cables, the ends of which should enter the manhole at least one-half a meter (20 inches) above the bottom.

Fig. 236 gives the dimensions adopted in Berlin. The New York manholes are generally built of brick and lined with cement in order to keep out moisture and gases. The opening



[illegible]

[illegible] with [illegible] between the [illegible]. [illegible] should always be provided with a sewer connection, wherever possible, [illegible] or running off water, which seems to leak [illegible] with the best construction.

[illegible] the [illegible] to be drawn [illegible] wire [illegible] in each [illegible] construction of the [illegible] may be drawn [illegible]. In this case the [illegible] wooden or iron [illegible] long, screwed or bolted together. The [illegible] passes through the [illegible] sections being screwed or bolted to one another, until the upward end appears in the [illegible]. There a rope [illegible] the last section and [illegible] through. Finally the [illegible] by a [illegible] [illegible] the rope [illegible] [illegible] [illegible] upon a [illegible] in the [illegible] through [illegible] the weight of the [illegible] with light [illegible] [illegible] in the [illegible]

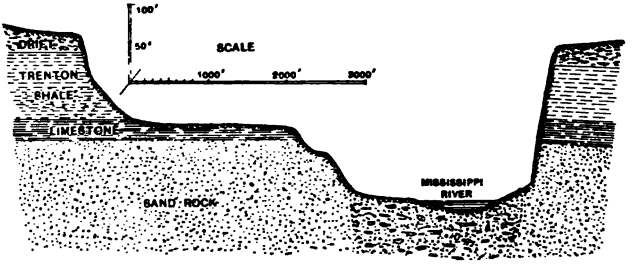


FIG. 237.

A portion of the telephone subway system in St. Paul, Minnesota, is probably the most unique in existence, consisting of a tunnel, with laterals, and drifts cut through the solid rock. The business section of the city stands on a bench, formed in past ages by the action of the Mississippi. Beneath a surface composed of a few inches of clay and alluvial soils is a ledge of Trenton limestone from ten to thirty feet in depth, and under* the Trenton lies the St. Peter sandstone; hardly a stone except in name, as it may be picked and shoveled without blasting. It is nearly a pure quartz sand, the lower strata almost white and the upper of varying shades of yellow. This formation, geologically known as St. Peter sandstone and locally as sandrock, is exposed along the river from ten miles above to twenty miles below the city. It is about 130 feet in thickness and lies approximately level from north to south and with a slight pitch to the west of 14 feet per mile. The elevation of the top of this sandrock is 767 feet above sea level and 84 feet above the river, which has an elevation of 683 feet above sea level. (Fig. 237.)

Through this sandstone was cut a tunnel or subway some two miles in length, nearly seven feet in height, and four feet in width. In constructing the tunnel, a shaft was first drilled through the limestone to the sandrock, when the only tools required were picks of special forms. The material cut away was placed in buckets, wheeled to the shaft and hoisted to the surface or dumped

* "The Sandrock Sewers of St. Paul, Minnesota," a paper read before the American Society of Civil Engineers, at the annual convention in June, 1894, by George C. Wilson, to whom the writer is also indebted for the diagrams and other information relating to the tunnel.

[This was received too late for insertion in regular order, and is believed to be too interesting to leave for a later issue.—THE EDITOR.]

FIG. 238.

directly into the river from the opening in the branch leading to the Mississippi. The average cost of completing the tunnel was about $1 a lineal foot, and the manholes, averaging 30 feet in depth, cost about $3 a foot in depth.

The tunnel is perfectly dry at all times, no moisture being noticeable anywhere, except a trifle around the manholes during wet weather, and the very slight condensation on the surface of the metal in brackets, ladders, distributing boxes, etc.

The cable capacity of the tunnel is practically unlimited, and the okonite and Patterson cables rest in iron brackets placed along the wall to the respective distributing boxes containing a cable head. In connecting circuits from the tunnel to the telephones of subscribers, a block system of distribution is used. In each block or circumscribed area a hole is drilled to the level of the tunnel and a two-inch or three-inch iron pipe driven downward. The lower end of the pipe is then reached by cutting a narrow drift at right angles to the tunnel, and an elbow fastened to the

pipe. A small cable or the necessary number of wires are then passed upward through this iron pipe to the surface and connected to the respective telephones in the usual manner.

From the manhole adjacent to the exchange a 24-inch sewer pipe, containing 3-inch iron tubes, is laid to the cable well in the basement of the exchange, and through these iron tubes the cables are led to the distributing board.

Mr. P. G. Reynolds, superintendent of construction of the Northwestern Telephone Exchange Company, who planned the tunnel and under whose supervision it was completed, has insured perfect ventilation at all times by connecting the main tunnel by means of a shaft to the high stack of the county steam plant on the opposite side of the street from the exchange.

EDITORIAL OUTLOOK.

Rich Kansas, or Blind Kansas?

So much has been written about "poor old Kansas" and the sufferings of her poverty-stricken people, that we had been led to believe that there was no money to throw away in that section of our country. But, according to a local item in the daily paper, the contrary must be true, and Kansans have money to burn. The item reads: "The Harrison Telephone Exchange, Topeka, Kansas, was sold at sheriff's sale, for $8,000, on September 19. This exchange has been in operation about three years, and has netted a loss of about $50,000 for its various owners. It is the third telephone exchange started in opposition to the Bell exchanges that has been sold at sheriff's sale in Kansas within fifteen months." Is the Emporia *Gazette* to blame for asking: "What's the matter with Kansas?" and then answering the question, "Kansas is all right! She started in to raise hell, and she seems to have an overproduction."

FRED DE LAND.

Perpetual Motion.

There is a valley in the North wherein abideth favored mortals who erstwhile have dealt in lumber and in salt (that shining white substance that makes potatoes taste bad when you don't put any on, as Johnnie would express it)—a valley that is the mecca of him who encompasseth the simple problem known as perpetual motion; or of him who hath perfected telephones that in no wise infringe, yet possess a battery transmitter that is automatically cut in and out of circuit. The last pilgrim carried away only $1,500 in the inner pocket of his vestment, but there are others who have done far better. His simple device consisted of a storage battery, a motor and a dynamo. Perpetual motion and a fair income were easily obtained by first having the battery charged at the lighting station, then connecting the motor, and belting the dynamo to the motor. "The current in the battery drives the motor, the motor drives the dynamo, and one-third of the current from the dynamo suffices to charge the battery, the other two-thirds being

serviceable for lighting or power purposes." Well, the pilgrim's heart failed at the critical moment or he could just as well have carried away $15,000, as a tenth of that sum. Yet he did fairly well. Time passes on and another weary pilgrim appeareth on the scene in the small of the moon. But before the queen of night has rounded out her glory he has shaken the dust of the valley from off his feet, and his wealth has increased many thousandfold, while a deluded mortal possesses the sole and exclusive right to introduce "a noninfringing telephone system" in a rich and progressive community. F. DE L.

RECENT PUBLICATIONS.

ELEKTRO-METALLURGIE. Die Gewinnung der Metalle unter Vermittlung des elektrischen Stromes von Dr. W. Borchers. II Edition. Braunschweig: Harald Bruhn, 1896. 393 pages, 6 by 9½; 188 illustrations; paper, uncut, price 14 marks.

This is a second edition of Doctor Borchers' work already well-known to electro-metallurgists. The book has been very much enlarged and completely revised, and is enriched by 188 well chosen and well executed illustrations. The author first gives a short sketch of modern electrochemical theory, but refers the reader to the works of Ostwald and Nernst for a more complete exposition of the subject. Then follows an account of the methods of extraction and preparation of each of the metals that has been obtained by means of the electric current. The metals are taken up in order, commencing with the alkali and earth metals. In presenting the processes for the preparation of each metal or its alloy reference is made to the literature upon the subject, but only those processes are given which have been successful or give promise of success. It was a difficult task to make proper selections from patents and other published description of processes, but this task has been judiciously performed by Dr. Borchers. The work before us is especially valuable to the student and investigator of electro-metallurgy, and will be useful to the technical man who wishes to know all that has been done that contributes most to the progress of this art. A. J. ROGERS.

TRAITÉ THEORIQUE ET PRATIQUE DES COURANTS ALTERNATIFS INDUSTRIELS. Par F. Loppe and R. Bouquet. Paris: E. Bernard & Cie, 53 Quai des Grands-Augustins, 1896. Two volumes; 750 pages, 6 by 9; 400 illustrations; price, 25 francs. (Vol. I, Theory, price, 10 francs; Vol. II, Practice, price, 15 francs.)

In this volume the authors have made good their promise given in the first volume to illustrate by examples in the second volume, the problems that arise in practice. It is not the theoretical side of alternating currents that is short on good literature, but the practical side, and a *good* contribution to this part, therefore, is always welcome. As a whole, the second volume before us is as satisfactory as it can be made. The following subjects are treated in full: Alternators, motors, transformers, transmission and distribution of current and current measurements. The book is not, as so many books are, a collection of nice cuts and a general description thereof, but contains working drawings in miniature with plenty of dimensions, a boon to the designer. There is no necessity to go into details, a few remarks only are prompted. The motor part is very elaborate, perhaps the best so far published. The theory of asynchronous motors is repeated in this volume on account of errors overlooked in the theory given in the first volume; besides, the new theory is much simpler than the earlier one, another welcome factor. The authors take up the question of economy, considering engines and their price in relation to the plant; but only a few pages of such useful matter are presented, yet it is a decided step to the better, as the cost and efficiency of the steam plant is no less important than the electric plant itself. Perhaps in the second edition this chapter will be extended. To judge by the quality of the whole treatise, there will soon be a demand for a second edition, as it cannot be denied that these two volumes are of the greatest value to the student as well as the scientific and practical engineer. F. J. DOMMERQUE.

Electrical Engineering

DECEMBER, 1896.

ELEMENTS OF COMPLEX QUANTITIES AND VECTORS WITH REFERENCE TO THEIR USE IN ALTERNATING CURRENT WORK.*

BY FRANZ J. DOMMERQUE, M. E.

Inverse Hyperbolic Functions.— Given $y = \sinh^{-1} \varkappa$.

By definition, $y = \sinh^{-1} \varkappa = -j \sin^{-1}(j \varkappa) = \dfrac{\sin^{-1}(j \varkappa)}{j}$ or $\sin^{-1}(j \varkappa) = jy$, whence $j \varkappa = \sin jy$.

We know that $\sin jy = j \varkappa = \dfrac{\varepsilon^{-y} - \varepsilon^{y}}{2j}$ multiplying by $2j$ we have $-2 \varkappa = \varepsilon^{-y} - \varepsilon^{y}$.

Let $\varepsilon^{y} = z$, we can then write $-2 \varkappa = z^{-1} - z$. Multiplying both sides of the equation by z, we obtain

$$z^2 - 2 \varkappa z - 1 = 0$$

hence $$z = \varkappa + \sqrt{\varkappa^2 + 1} = \varepsilon^{y}$$

and therefore

$$y = \sinh^{-1} \varkappa = \log_{\varepsilon} \left(\varkappa + \sqrt{\varkappa^2 + 1} \right) \qquad (116)$$

Similarly we find

$$y = \cosh^{-1} \varkappa = \log_{\varepsilon} \left(\varkappa + \sqrt{\varkappa^2 - 1} \right) \qquad (117)$$

If $y = \tanh^{-1} \varkappa = -j \tan^{-1}(j \varkappa) = \dfrac{\tan^{-1}(j \varkappa)}{j}$, we have

$$\tan^{-1}(j \varkappa) = jy, \text{ and } j \varkappa = \tan jy;$$

but $\tan jy = j \varkappa = \dfrac{\varepsilon^{-y} - \varepsilon^{y}}{\varepsilon^{y} + \varepsilon^{-y}} \times \dfrac{1}{j} = \dfrac{\varepsilon^{y} - \varepsilon^{-y}}{\varepsilon^{y} + \varepsilon^{-y}} \times j$, whence

$$\varkappa = \frac{\varepsilon^{y} - \varepsilon^{-y}}{\varepsilon^{y} + \varepsilon^{-y}};$$

multiplying numerator and denominator by ε^{y} we obtain

$$\varkappa = \frac{\varepsilon^{2y} - 1}{\varepsilon^{2y} + 1}$$

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$$(\varepsilon^{2y} + 1)\varkappa = \varepsilon^{2y}\varkappa + \varkappa = \varepsilon^{2y} - 1$$

$$\varepsilon^{2y}(1 - \varkappa) = 1 + \varkappa, \text{ and } \varepsilon^{2y} = \frac{1 + \varkappa}{1 - \varkappa}$$

$$\text{whence } 2y = \log_\varepsilon \frac{1 + \varkappa}{1 - \varkappa} \text{ and } y = \tanh^{-1}\varkappa = \tfrac{1}{2}\log_\varepsilon \frac{1 + \varkappa}{1 - \varkappa}$$

Circular Functions of Complex Quantities.— In the trigonometrical function

$$\sin(\varkappa + y) = \sin\varkappa \cos y + \cos\varkappa \sin y$$

give y the imaginary value jy; then

$$\sin(\varkappa + jy) = \sin\varkappa \cos jy + \cos\varkappa \sin jy.$$

Hence by the use of the notation of the hyperbolic functions

$$\sin(\varkappa + jy) = \sin\varkappa \cosh y + j\cos\varkappa \sinh y \qquad (118)$$

and similarly

$$\cos(\varkappa + jy) = \cos\varkappa \cosh y - j\sin\varkappa \sinh y \qquad (119)$$

and

$$\tan(\varkappa + jy) = \frac{\sin 2\varkappa + j\sinh 2y}{\cos 2\varkappa + \cosh 2y} \qquad (120)$$

Hyperbolic Functions of Complex Quantities.— Giving in the equation

$$\sinh(\varkappa + y) = \sinh\varkappa \cosh y + \cosh\varkappa \sinh y$$

y the value jy, we obtain

$$\begin{aligned}\sinh(\varkappa + jy) &= \sinh\varkappa \cosh(jy) + \cosh\varkappa \sinh jy \\ &= \sinh\varkappa \cos y + \cosh\varkappa\, j\sin y,\end{aligned}$$

or,

$$\sinh(\varkappa + jy) = \sinh\varkappa \cos y + j\cosh\varkappa \sin y. \qquad (121)$$

Similarly, giving in equation

$$\cosh(\varkappa + y) = \cosh\varkappa \cosh y + \sinh\varkappa \sinh y$$

y the value jy, we obtain

$$\begin{aligned}\cosh(\varkappa + jy) &= \cosh\varkappa \cosh(jy) + \sinh\varkappa \sinh(jy) \\ &= \cosh\varkappa \cos y + \sinh\varkappa\, j\sin y,\end{aligned}$$

or,

$$\cosh(\varkappa + jy) = \cosh\varkappa \cos y + j\sinh\varkappa \sin y \qquad (122)$$

Professor Houston and Kennelly presented before the American Institute of Electrical Engineers a sheet of curves, by the aid of which the hyperbolic sines and cosines of vectors may easily be found.* By permission of the American Institute their graphical determination is here inserted. As their construction involves the use of polar coördinates, a brief explanation of the latter will be given.

* Transactions of the American Institute of Electrical Engineers, April 17, 1895, page 133, etc.

Polar Coördinates.— In Fig. 25 a point M may be located on an infinite straight line (which may be the axis of X), and this point may be used for determining the location of a point P, on a curve PQT. The line connecting P and M forms with the axis of X an angle, θ; this angle being determined by any geometrical function of θ, as $\sin\theta$, $\cos\theta$, $\tan\theta$, etc., while MP (usually designated by r) is the vector of the point P. The point M is termed "pole." Now r and θ may take the place of

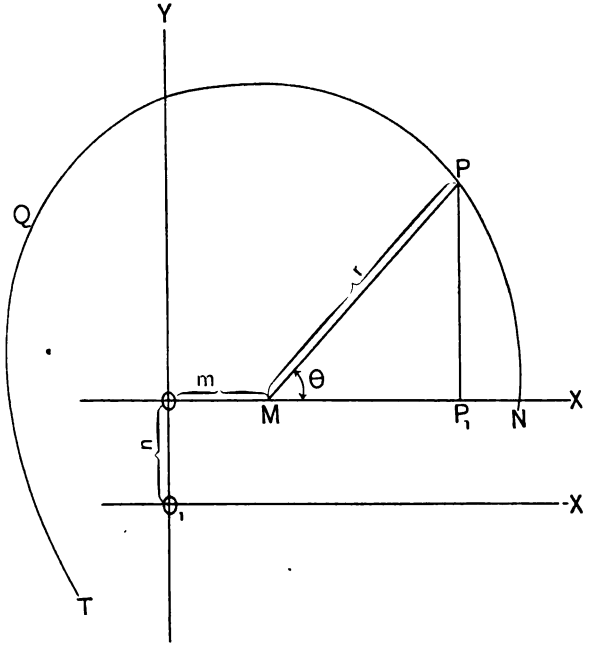

FIG. 25.

coördinates, and to distinguish them from rectangular coördinates they were given the name "polar coördinates." Rectangular coördinates can easily be transformed into polar coördinates, and vice versa.

If the axis of X in the polar-coördinate system coincides with the axis of X in the rectangular-coördinate system, the rectangular coördinates of the point P are found as OP_1 and P_1P; but

$$OP_1 = OM + MP_1 = m + r\cos\theta$$

and $$y = P_1P = r\sin\theta$$

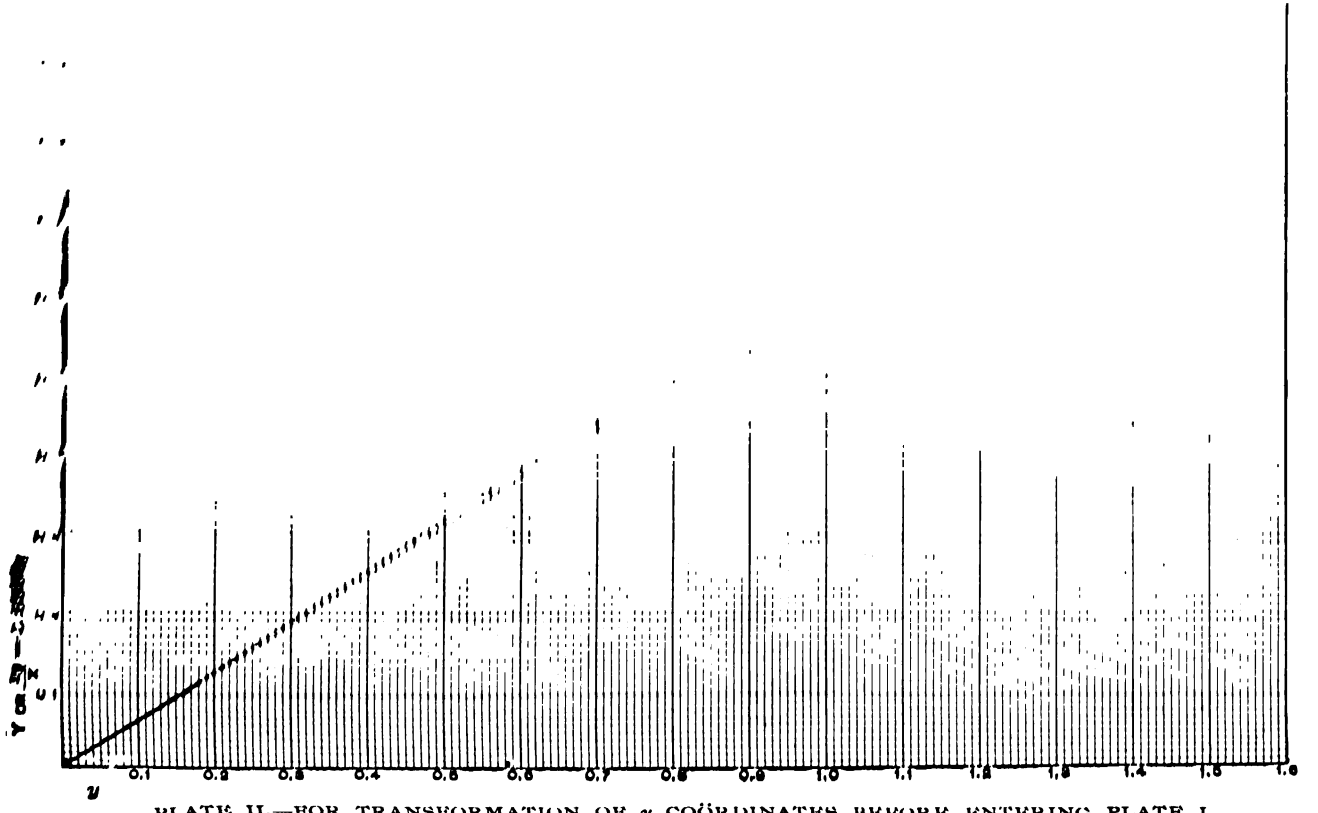

PLATE II.—FOR TRANSFORMATION OF y COÖRDINATES BEFORE ENTERING PLATE I.

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thus, the rectangular coördinates expressed in terms of polar coördinates are

$$x = m + r\cos\theta$$
$$y = r\sin\theta$$

Should, however, the axis of X, as X_1 of the rectangular-coördinate system, be at a distance n, parallel to the axis of X of the polar-coördinate system, x would remain $= m + r\cos\theta$, but y would become $= n + r\cos\theta$.

Inversely, if polar coördinates are to be changed to rectangular coördinates, we have the following relations:

$$r^2 = (P_1P)^2 + (MP_1)^2 = y^2 + (OP_1 - OM)^2$$
$$= y^2 + (x - m)^2$$

therefore $$r = \sqrt{y^2 + (x - m)^2}$$

If $m = 0$, we have

$$r^2 = y^2 + x^2 \text{ and } r = \sqrt{y^2 + x^2}$$

$$\sin\theta = \frac{y}{r} = \frac{y^2}{\sqrt{y^2 + x^2}}$$

$$\cos\theta = \frac{MP_1}{r} = \frac{x - m}{r} = \frac{x - m}{\sqrt{y^2 + x^2}}$$

$$\tan\theta = \frac{y}{x - m}$$

This explanation enables us to understand Professor Houston and Kennelly's description of the use of their table, which is given here in full:

"If we have a point p, situated in a plane, and we know its rectangular coördinates x and y, we may readily determine its polar coördinates r and θ by calculation. Thus, if $x = 1$ and $y = 1$, $r = 1{,}414$ and $\theta = 45°$. We may either transform the coördinates by computation in each case, or we may carry out the process graphically. This could be done by drawing lines parallel to x and y at suitable distances apart, intersecting everywhere at right angles, and marking off from the point $x = 0$, $y = 0$, as center, a series of concentric circles, and radii intersecting all these circles at successive angular distances at right angles. We could then find directly from the diagram, by inspection, the polar coördinates of any point whose rectangular coördinates are given.

"Plate I is intended for the purpose of giving by inspection the polar coördinates of a vector point, representing the hyper-

bolic sine or cosine of a given vector, whose rectangular coördinates x and y are known. A series of ellipses represent values of x, and a series of hyperbolas, everywhere intersecting the ellipses at right angles, represent the values of y. At the intersection of any ellipse value of x with the hyperbola value of y will be the radius and angle, i. e., the polar coördinates of the hyperbolic sine or cosine, according to the direction in which the plate is held by the observer.

"If, for example, we take the coördinates X = 0.2 and Y = 0.7, and enter the plate for hyperbolic cosines, we will find, as in Fig. 26, that starting from the horizontal line 0 0, or the

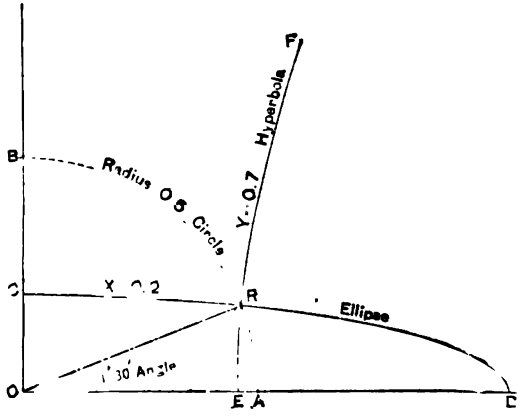

FIG. 26.

Determination of the hyperbolic cosine of the plane vector whose coördinates are $X = 0.2$ and $Y = 0.7$. Result $0.5 \angle 21° 15'$.

major axis of the ellipses at the right-hand extremity, and counting Y, counter-clockwise, we find a hyperbola E R F, Fig. 26. This hyperbola is marked Y = 0.7. We then find the ellipse X = 0.2, C R D, and, at the intersection of these two lines will be the point whose polar coördinates give the hyperbolic cosine of the vector sought, namely $R = 0.5 \angle 21° 15'$, for R lies on the circle of radius 0.5 at an angle, counted counter-clockwise from O D, of approximately 21° 15'.

"Turning Plate I through 90° and again starting in this position, from the horizontal line 0 0, or the line of minor axes of the ellipses, we enter the plate for the hyperbolic sines of the same vector whose coördinates are X = 0.2 and Y = 0.7. We travel

counter-clockwise from the right over the same ellipse as previously employed, and at its intersection R, Fig. 27, with the hyperbola C R D of $Y = 0.7$, we have the point whose polar coördinates give the hyperbolic sine required. This point lies between the circles $R = 0.9$ and $R = 0.95$, but nearer to the former, and approximately at a radius $R = 0.92$ and an angle of approximately $84° 15'$.

"It will be observed that the ellipses are carried by successive steps of 0.05 as far as $x = 1.25$, so that the diagram is limited in the range of abscissas to this amount. Since, however, counting counter-clockwise, Y passes from 0 at the right-hand side to 1 at the vertical, 2 at the left-hand side, 3 at the lower vertical and 4 at the starting point on the right-hand, and so on, 1 to every 90° or 4 per revolution around the diagram, any value of Y can be accommodated.

"The diagram, therefore, becomes practically, to a moderate degree of approximation, a graphic table of hyperbolic sines and cosines of any vector quantity obtained between the rectangular coördinates $x = 0$, $Y = 0$ and $X = 1.25\ Y = \infty$. This range is sufficient for most problems that present themselves.

"In order, however, to obtain this extended range of Y by repeating its value in successive cycles of 4, it has been necessary to alter the numerical values of the ordinates Y. Since the natural period of revolution is 2π or 6.2832, corresponding to $Y = 4$ in the diagram, each unit ordinate of the diagram corresponds to $\frac{2\pi}{4}$ or 1.5708. In entering the plate, the ordinate of the vector must be reduced in the ratio of 1 : 1.5708 or be multiplied by 0.6366.

"Plate II affords a graphical means of accomplishing this reduction of the y coördinate by inspection. If, for example, we look for $y = 1.1$ along the axis of abscissas, we find $Y = 0.7$ as the corresponding ordinate. So that, having found the abscissa x and ordinate y corresponding to a given vector, we find from Plate II Y, the transformed value of y, and enter Plate I with x and Y."

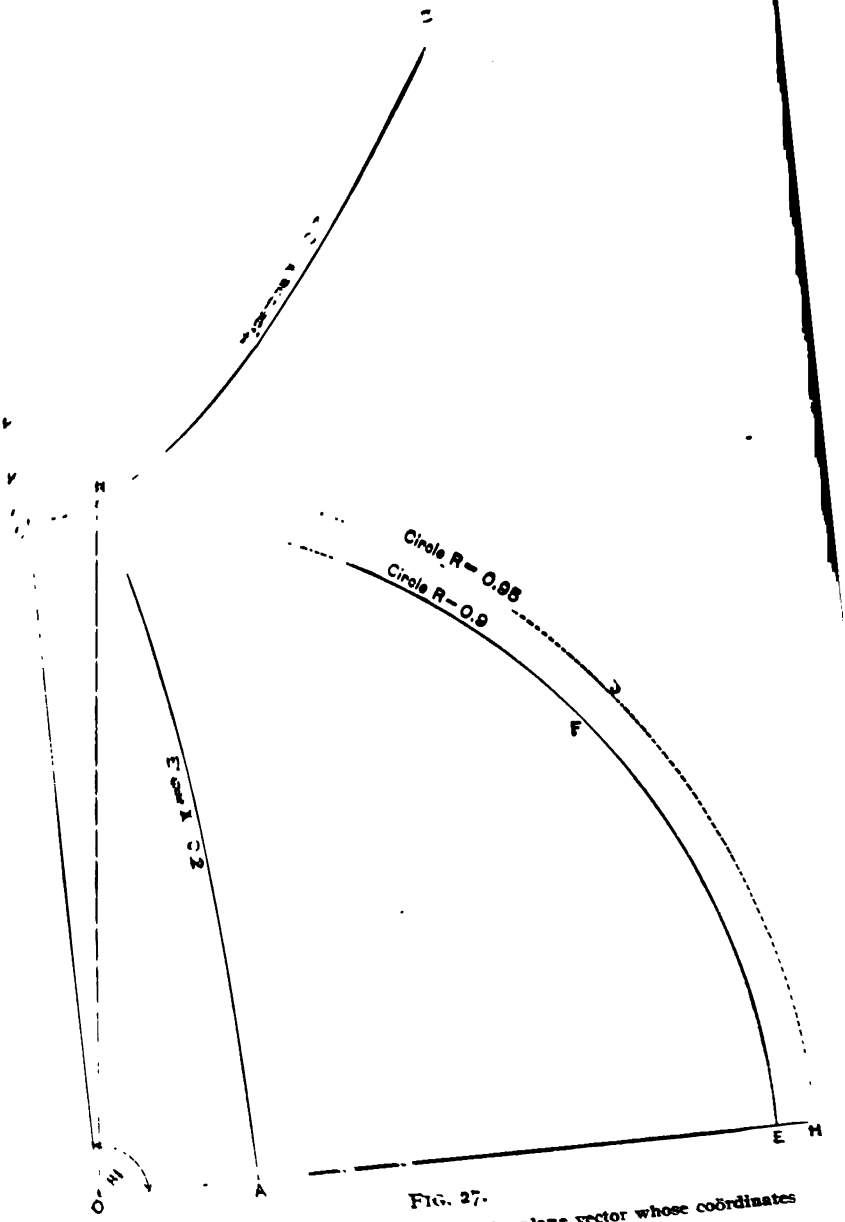

FIG. 27.

Determination of the hyperbolic sine of the plane vector whose coördinates are X = 0.2 and Y = 0.7. Result 0.02 84° 15′.

THE BASIS OF TELEPHONE CHARGES.

BY FRED DE LAND.

When a resident of a city contracts for telephone service a telephone is placed upon the wall or the desk in home or office or factory, and connected by two copper wires to a number on the switchboard corresponding to the number on the telephone. And to this same switchboard are connected the other wires entering the telephone exchange. Then, with the aid of a cord or loop having terminal plugs, the operator at the switchboard temporarily joins the lines of any two subscribers.

Now the function of the telephone exchange is to temporarily connect or link together all the lines leading into or radiating out from the exchange to every part of the city in such manner as to permit of conversations; and this linking together of the calling and the called subscriber's lines virtually converts these two independent lines into one temporary private line.

Having provided the means whereby one subscriber may talk with any other subscriber, it is clear that the number of conversations which a telephone exchange must be prepared to make will increase geometrically as the number of lines increase. This is clearly set forth in the following table, wherein it is shown that while an exchange having but ten subscribers can only effect a total of ninety combinations; that is, each and every one of the ten subscribers can be connected to the nine other subscribers; yet in an exchange having only ten times ten, or a total of 100 subscribers, the number of possible combinations or linkings increases to 9,900; for 500 subscribers it increases to 249,500, and so on.

While this brief table clearly portrays how manifold is the increase in combinations, yet the experienced subscriber will also perceive how the scope of the service increases in groups of exchanges without any increase in rental charges. That is, a subscriber to an exchange of 500 subscribers rarely pays more for the service supplied than in an exchange having but 100 subscribers. Yet the possible combinations afforded in the former are 249,500, and in the latter but 9,900.

And to the thoughtful subscriber this table will also suggest how the item of labor must necessarily enter more and more into switchboard service as the subscribers increase in number, for with the increase in the number of subscribers comes a far greater increase in the number of calls per subscriber, and to rapidly and successfully handle this marked increase in calls necessitates not only an increase in the operating force, but also a complete switching apparatus for each operator or group of operators as soon as the number of subscribers reaches that point where it is economy to "multiple" the system.

TABLE SHOWING POSSIBLE COMBINATIONS.

With	1 subscriber	there	are	no	possible	combinations.
"	2 subscribers	"	"	2	"	"
"	5	"	"	"	20	"	"
"	10	"	"	"	90	"	"
"	20	"	"	"	380	"	"
"	30	"	"	"	870	"	"
"	40	"	"	"	1,560	"	"
"	50	"	"	"	2,450	"	"
"	100	"	"	"	9,900	"	"
"	200	"	"	"	39,800	"	"
"	300	"	"	"	89,700	"	"
"	400	"	"	"	159,600	"	"
"	500	"	"	"	249,500	"	"
"	600	"	"	"	359,400	"	"
"	700	"	"	"	489,300	"	"
"	800	"	"	"	639,200	"	"
"	900	"	"	"	809,100	"	"
"	1,000	"	"	"	999,000	"	"
"	1,100	"	"	"	1,208,900	"	"
"	1,200	"	"	"	1,438,800	"	"
"	1,500	"	"	"	2,248,500	"	"
"	2,000	"	"	"	3,998,000	"	"
"	3,000	"	"	"	8,997,000	"	"
"	4,000	"	"	"	15,996,000	"	"
"	5,000	"	"	"	24,995,000	"	"
"	6,000	"	"	"	35,994,000	"	"
"	7,000	"	"	"	48,993,000	"	"
"	8,000	"	"	"	63,992,000	"	"
"	9,000	"	"	"	80,991,000	"	"
"	10,000	"	"	"	99,990,000	"	"

In the small exchange of 100 to 300 subscribers the modern switchboard is so arranged with complete panels of 100 drops, that each operator has within reach the entire number of lines

entering the exchange, anyone of which is at once available, and thus can easily answer all calls in routine service. But in exchanges having a thousand subscribers every one of the dozen or more operators must be provided with the means of connecting with the aid of short wires, called "trunk lines," the different panels placed in front of each operator at the switchboard; or the terminals of the lines must be brought out and made available to groups of two or three operators at each of a number of panels in the switchboard, in order that each operator or each group of operators may reach directly or indirectly every line entering the exchange. This is called "multipleing" the circuits, and on some exchanges it is necessary to bring out or "multiple" the lines as many as forty-four times.

But when the number of subscribers exceeds 3,000 a still different phase is presented. Experience has taught that it is neither expedient nor economical to connect so great a number of lines to one switchboard. Hence it is the practice to establish branch exchanges and connect these branches with the main exchange, and also with each other. This necessitates a large increase in the relative investment per subscriber, in the operating force, and in the skilled experience requisite to insure satisfactory service, nearly all of which may properly be called a non-productive investment. Thus, in Chicago, there are ten branch exchanges in addition to the main exchange. And yet a subscriber can instantly secure conversational right of way to any one of the other 10,000 subscribers, either by calling up any one of the branch exchanges, or the main exchange.

In some of these branch exchanges it is comparatively easy to anticipate the maximum rate at which calls will enter a given exchange during a given period, and thus a limited number of operators only need remain on duty; while in certain other branch exchanges the number of calls are influenced and may vary with the rise or fall of the market, or with certain receipts and shipments of lumber or grain, or changes in the weather or in the seasons. An exchange having a large number of residence subscribers may find its maximum load line between 8 and 11 A.M., and 5 and 8 P.M., while the exchange having many subscribers located in the down-town wholesale district will rarely have a call from that section after 6 P.M. But little service is required by the lumber section during the winter months, while

many more than the average connections are required in spring and summer.

Thus in many exchanges two or three operators could handle all the calls entering in a given time after 7 P.M., provided all the panels were easily accessible to this group of operators. But owing to the length of the switchboard and the arrangement of the panels, there must be one or more night operators for each group of panels if the night service is to be thoroughly supervised and the quality of the service maintained.

In small exchanges the average number of subscribers that one operator can expeditiously care for is about one hundred during daylight hours, while in the larger exchanges where the calls per subscriber are many times more than in the small exchange, one operator can only serve about one-half that number in a prompt and satisfactory manner.

THE RISE AND FALL OF COMPETING TELEPHONE EXCHANGES.

BY FRED DELAND.

At first thought it appears perfectly feasible to make a competing telephone exchange profitable property, yielding good returns on the investment; and during the first few months nearly all competing exchanges flourish in a financial sense. For the unhealthy public sympathy stimulated for selfish ends enables town councils to grant franchises containing very liberal provisions, while the interest taken by many citizens insures a large number of subscribers from the start. But though opened under the most favorable auspices, yet the records show that gradually one competing exchange after another suspends operations, and the plant is sold for what it will bring — often for old junk — unless the franchise is a peculiarly liberal one. The cause is easily found. The closed exchanges at Waukesha, at Topeka, at Fort Smith, at Selma and at twenty other points all tell the same tale: "Inability to secure an income from low rates that would warrant the expenditure necessary to secure the talent requisite to maintain and operate the plant in a manner that would insure prompt and efficient telephone service." This truthful and official statement is the whole story in a sentence. Nowhere was any legal action taken by the Bell Company, though in every one of these exchanges apparatus was used that no doubt infringed patent rights owned or controlled by the Bell interests. But everywhere the Bell service formed the standard by which the new service was measured, and the expectations that a telephone service far superior to the Bell would be supplied at half the rates formerly charged were never realized. And when the quality of the service continued to depreciate, one after another of the subscribers refused to continue renting the new instruments, and the end soon came. Then the doors were closed, the plant sold for what it would bring, usually about one-fifth or one-tenth of its cost, and the original investment proved a total loss.

Each failure has but served to further illustrate the well-known truth that the question of low rental charges plays a

secondary part in the problem of supplying satisfactory service. The quality and the rapidity of the service are the essential factors in successful telephone exchange management. For the progressive subscriber must have high-class service, and for such service he will pay a reasonable price. Investigation by competent business men has repeatedly shown that telephone rates are reasonable when proper allowances are made for the maintenance and operation of the plants, and when subways, cables, overhead lines, operating appliances and the service are maintained at the highest standard.

Rates established on too cheap a basis lead to inevitable disaster in the telephone business as in any other enterprise. That this is true is clearly indicated by the experience gained in the twenty-four following-named towns or cities, no longer burdened with a competing exchange :

Topeka, Kansas, closed September, 1896.
Fort Smith, Arkansas, closed September, 1896.
Jefferson, Texas, closed November, 1894.
Great Barrington, Mass., closed March, 1896.
Somerville, New Jersey, closed June, 1896.
Memphis, Missouri, closed September, 1894.
Freehold, New Jersey, closed March, 1896.
Selma, Alabama, closed April, 1896.
Richfield, Connecticut, closed May, 1896.
La Grange, Illinois, closed May, 1896.
Nevada, Missouri, closed June, 1896.
Clarksville, Tennessee, closed December, 1895.
Waukesha, Wisconsin, closed June, 1896.
Augusta, Maine, closed May, 1895.
Big Rapids, Michigan, closed May, 1895.
Uhrichsville, Ohio, closed May, 1896.
Argos, Indiana, closed July, 1896.
Pittsburg, Kansas, closed May, 1896.
Madisonville, Kentucky, closed.
San José, California, closed October, 1896.
Sayville, Long Island, closed August, 1895.
Far Rockaway, Long Island, closed October, 1895.
Ypsilanti, Mich., closed August, 1896.
Fayetteville, closed October, 1895.
East Liverpool, Ohio, closed.
Highland Park, Ill., closed December 14, 1895.

THE MANUFACTURE OF WIRE.*

BY FREDERIC A. C. PERRINE, D.Sc.

While the extent of the territory through which gutta-percha is found is comparatively limited, and in that territory the best gum is obtained only from the trees of a single species, india rubber is found in greater or less quantities through all climates, and is obtained from the juices of a very great number of entirely dissimilar plants; indeed, the commercial supply of india rubber does not even come from a single natural botanical order, nor does that of the highest quality come from a single species, it being often the habit to collect the juices of several species together and to use the gum obtained from the mixture.

The world's supply of india rubber is obtained from plants belonging to four entirely dissimilar natural botanical orders: Euphorbiaceæ, Moraceæ, Artocarpaceæ, Apocynaceæ. Some of these, as the Havea Brasilensis, from which the "Para" rubber of Brazil is collected, are trees rising to upward of sixty feet in height, while the rubber of Madagascar is obtained from a series of climbing shrubs or vines. In some countries rubber is obtained from a species of fig, and in our own country the common milk weed yields a very considerable amount of crude rubber which, however, has never been used commercially. As might be expected the rubbers from these different sources vary greatly in external character, though it is surprising to know that the chemical constitution of the many different rubbers is almost identical, while the great variation in the physical qualities is due to the fact that all rubber is composed of two constituent elements which occur in varying proportions in the different varieties. The first of these is a dry, fibrous, elastic material, not being readily soluble in benzole or its homologs; the other, a sticky semi-fluid substance readily and completely dissolved. The most useful are those which contain the largest amount of the dry fibrous substance, while in the inferior rubbers the proportion of the sticky gum preponderates. A further difference in the qualities of the various rubbers is due to the fact that the

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gum as it exudes from the tree or shrub is held in suspension by a considerable quantity of liquid ammonia from which it must be separated by coagulation, and the manner in which this separation is performed very often determines the quality of the rubber. All of the rubbers of commerce are collected in the forest by the natives of the territory where the trees grow, and as those plants which yield a large amount of rubber are almost exclusively tropical, the manufacturing processes partake of the indolent nature of the natives who collect the juice. This is done by making incisions in the plant and coagulating by many different methods, in some cases by allowing it simply to dry upon the arms of the collectors, in others the juice is heated over a hot smudge, while others perform the coagulation in vats by means of a solution of alum or by the aid of some acid plant juice. On account of these different methods of collecting, we are in doubt whether the inferior grades might not be vastly improved by the application of more intelligent methods in collecting, and indeed, we are led to believe that this might be so from the fact that the rubber coming from Peru seems vastly inferior to that coming from Brazil, although the trees are of the same species; that coming from Brazil being coagulated by the means of hot smoke, while that coming from Peru is coagulated by the means of an acid plant juice. However collected, rubber contains a great amount of impurities in the form of stones, twigs and chemical solutions which must be removed before it can be applied in any manufacturing process.

Of the many rubbers on the market those bearing the name of "Para" are collected from three different species of Euphorbiaceous trees, and contain the largest amount of elastic material and are coagulated in the best manner, being cured, as we have already stated, by the hot vapor rising from a smudge made from oily nuts; the next in quality is called Ceara, obtained from another tree of the same order in the Province of Rio de Janeiro; following these in quality is the gum from the shrubs of Madagascar, coagulated by the means of an acid juice — the difference between the three grades being less striking than would otherwise be expected. From the Artocarpaceæ we obtain the Cartagena and Guayaquil rubbers, coming respectively from New Granada and Ecuador, which varieties contain a larger amount of the inelastic sticky material and are consequently regarded as

being of an inferior quality. From the Apocynaceous trees we obtain a rubber bearing the name of Pernambuco, a quality still more sticky in character and containing a very large amount of water on account of the fact that coagulation is performed by the means of a saline solution. From Assam a good quality of rubber is obtained from the fig tree called Ficus Elastica, a common plant of our greenhouses and the only one generally known to us as a rubber plant. Besides those we have mentioned, rubbers are obtained in the West Indies, Mexico, and most of the Central and South American countries; inferior grades are also obtained over a large part of central Africa, and from Asia, Borneo, Malacca, Java and the surrounding countries, greatly varying in their qualities, though all except those we have mentioned are decidedly inferior to the Para rubber collected in Brazil.

On account of the wide range in quality of the gums available, the art of the rubber manufacturer consists in selecting those sorts which are best adapted to the service and from them producing a manufactured product which will be at the same time the most durable and the cheapest. Pure rubber is a gum which is perfectly odorless and nearly white, having a specific gravity of .915, though it is never obtained without color or odor on account of the means used for coagulating the juice, and although the odors can never be commercially removed from the rubber which has been so treated, it is possible to purify by washing so completely that the physical properties of the cleaned gum approaches closely those of pure rubber. Certain acid coagulants, however, seem to have a permanent effect in deteriorating the quality of the gum, and in consequence these kinds are not well considered even when they are obtained free from dirt and are otherwise satisfactory. The different sorts of rubber are received in various forms given them by the natives who collect the juice, these forms being sometimes bottles, balls, loaves, sheets or irregular pieces, but in most cases containing a certain amount of mechanically mixed impurities. In order to remove these and grade into "fine and coarse," the rubber is first cut by hand under warm water, and after the larger pieces of foreign matter are removed the cut gum is masticated between a pair of corrugated and toothed rollers under a stream of warm water which removes the impurities, whether chemical or mechanical, and at the same time dissolves the resin which has been formed by a

partial oxidization of the gum. While undergoing this process, gums, as received from the importers, lose from ten to twenty-five per cent of their weight and at the same time take up a very considerable quantity of water in the pores of the washed gum. This water must be removed by drying, for which purpose the gum is finally run through masticators into form of sheets, twelve to eighteen inches long and from six to ten inches wide, which are then hung in dark lofts where they dry for as long a period as is possible, remaining sometimes in the drying room for upward of a year after the rubber has been thoroughly cleaned. After rubber has been thoroughly masticated and dried it is readily consolidated into a mass by the application of pressure. Pure rubber sheet is obtained by cutting rubber which has been consolidated in this manner into large solid blocks, the cutting being performed by very rapidly moving knives acting under water.

Pure gum so derived is cellular in texture, absorbent and very adherent, all pieces freshly cut joining together so completely under the influence of their own weight that they cannot be again separated. In this state the dried gum will absorb from ten to twenty per cent of pure water, and from three to five per cent of sea water on continued immersion. Under the influence of light and heat pure rubber becomes oxidized in time into an inelastic brittle resin not readily adherent, and in consequence it is not possible to use the pure gum for the purposes of insulation, or for other purposes where its absorbent qualities will interfere with its usefulness, or where it is exposed to sunlight or heat.

The earliest attempts at insulating wire were made with pure rubber strip obtained in this manner, the strips being spirally wound upon the wire, and afterward consolidated by a slight amount of heat into a solid mass; but all of such attempts were failures on account of the readiness with which the rubber would absorb moisture, become oxidized, and be softened at an elevated temperature. A curious action between the rubber and the wire was also observed at the time of these attempts, the copper wire becoming slightly oxidized and the rubber rendered liquid at the surface of the conductor. It was subsequently found that this was due to the medium used for preventing adherence between the sheets of rubber, for which purpose use was made of soap and potash, substances which subsequently liberated oxygen and

grease, one of which would attack the wire, and the other the rubber.

Gradually this method of insulation has been abandoned in favor of the use of vulcanized rubber, which has more recently given place to a vulcanized compound of rubber which is called in the American trade "mechanical rubber."

Vulcanization consists in adding to pure rubber a certain proportion of sulphur, and heating the combined product. When this has been done the rubber loses its adherent properties, is less readily absorbent, and is rendered indifferent to changes of temperature, retaining its elasticity from temperatures below the freezing point to temperatures considerably above the boiling point. This mixing with sulphur may be performed either by heating the gum packed in finely divided sulphur, by painting the surface with a solution of chloride of sulphur in bisulphide of carbon, or by mechanically mixing the two substances together between heated rollers. The first method of packing in sulphur will obviously produce a very irregular product, and in consequence has been altogether abandoned in favor of the other more certain methods. The second method described, that of painting the surface with a mixture of chloride of sulphur and bisulphide of carbon, is not capable of producing uniformly vulcanized rubber in any except the thinnest sheets, and in consequence the method is now rarely used except for the vulcanization of thinly rubber-coated cloth, such as used in the manufacture of gossamer waterproofs. In the mixing process rubber which has been masticated and dried is weighed out with the proper amount of sulphur and other ingredients, and then passed many times between a pair of smooth steam-heated rolls called grinders, where it is mixed until the material becomes thoroughly uniform in character, when it is ready for application to wire for insulating, to be molded or to be rolled into any desired shape, and finally to be vulcanized. The amount of sulphur used in this mixture varies from five to twenty per cent of the entire mass, though so small an amount as three per cent is occasionally used, the amount of sulphur determining the hardness of the vulcanized product, it being possible with a large admixture of sulphur to produce a hard inelastic material commonly called hard rubber, vulcanite or ebonite. The final process of vulcanization consists of heating this mixture after it has been molded into its final shape in either

a dry heat or a steam bath at a temperature of between 130° and 150° Cent. for a period of from half an hour to an hour and a half. During this heating the rubber at first expands greatly and tends to become very porous, but finally assumes a permanent character which is not affected by any moderate change of temperature, either of heat or cold. In consequence of the early tendency to become porous, it has been found necessary in vulcanizing to support the rubber in position, and thus obtain a perfectly solid product.

While vulcanized rubber is thus stable in character, as we have stated, it is only so when the sulphur remains in a permanent state of combination with the rubber, but it is not always possible to assume that this will be the case, on account of the fact that there seems to be a tendency of the sulphur to evaporate and crystallize out of combination with the rubber, leaving the vulcanized product in such a state that it may subsequently become oxidized and brittle. This action more readily occurs with pure vulcanized gum than with the mechanical rubber of which we have already spoken, and in consequence the latter is considered to be a more durable product. For obtaining this material the gum is mixed not only with sulphur but also with many other substances, some of which are permanently inert, and others undoubtedly combine with the rubber and sulphur into a new compound. Of the inert substances used may be mentioned the finely ground minerals, such as talc, mica, chalk, etc. The possibly active materials in such mixtures are oxides of lead, zinc or other metals which probably combine with the sulphur to some extent, or may influence the rubber itself. Of those which undoubtedly combine with the rubber, and in some cases clearly improve its lasting qualities, may be mentioned many resins, some of which are pure natural resins, and others are resins obtained by the oxidization of drying oils similar to linseed or nut oil, and in some cases even mineral waxes are employed, though there is much dispute among rubber manufacturers as to whether these substances improve or deteriorate the quality of the rubber.

Many manufacturers make advantageous use of rubber substitutes which by others are considered adulterations and injurious to the quality of the manufactured product; these consisting principally of oxidized oils, paraffin, resins and rubber shoddy;

and though it is undoubtedly a fact that all such substances are capable of great abuse, it is nevertheless true that the skillful employment of these substitutes will produce a product of good quality and will sometimes even result in a superior article to that which can be produced with the ordinary qualities of pure gum. Purification of resins for this purpose consists in the entire elimination of all organic acids, and by their employment a rubber compound is produced more readily softened by heat than can be obtained with any pure gum. Their legitimate application consists of their use in the manufacture of rubber-coated cloth called "friction cloth," and which forms the taping material for finishing the outside of large cables and rubber wires. The oxidized oils are produced by a continued heating of drying oils in the presence of some metallic oxide readily reducible, such as red lead, the product being a flexible resin of a gummy nature, often hard to distinguish from the inferior grades of rubber. Rubber shoddy is a compound obtained by subjecting old rubber which has been mixed with sulphur and vulcanized, to a treatment with steam, sulphuric acid and chloride of zinc, the effect being that most of the vegetable fibers and the sulphur contained in the compound are removed. When the rubber compound thus manufactured consists of clippings from articles to be vulcanized and treated before vulcanization, the shoddy obtained differs but little from pure rubber; the treatment amounting to nothing more than a chemical solution of the fibers of cloth or other foreign substances retained in the clippings. This class of shoddy is obtained in only very limited quantities, and it is perhaps unjust to class such a material with the more common rubber shoddy which is produced by the devulcanization of completed mechanical rubber goods, such as are purchased by the rubber shoddy manufacturers from the rubber junk dealers; this latter form of shoddy is more difficult to obtain entirely free from fibrous materials, while the devulcanizing process, although removing a greater part of the sulphur of vulcanization, does not return the rubber to its original condition, nor does it remove the mechanical admixtures of earths and oxides employed in manufacturing the original articles. In consequence, the proportion of rubber in rubber shoddy is an uncertain quantity, so that its employment is attended with a considerable danger of producing an irregular product. In spite of this difficulty, however, it is undoubtedly

true that certain grades of rubber shoddy may be so employed by skillful rubber mixers as to increase the mechanical strength of the resultant compound, and many rubber manufacturers using a compound containing an admixture of high-grade rubber shoddy obtain a covering which gives good service when exposed to the action of the elements, while others who never employ this material are unable to obtain a wire insulation which will withstand the oxidizing action of the light to an equal extent. The reason for this apparently being that the previous vulcanization has rendered the rubber unchangeable under the ordinary influences which will deteriorate compounds of pure gum.

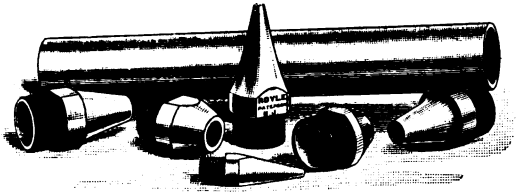
Among the earliest discoverers of this principle may be mentioned A. G. Day, the inventor of "Kerite" insulated wire, and of hard rubber, who, after very many years of experimentation on the vulcanization of linseed oil, abandoned the material as well as pure vulcanized rubber for a vulcanized compound of oxidized linseed oil and rubber, combined with various vegetable oils; thus producing a material which, while having a specific insulation resistance somewhat less than pure rubber, still obtained a wire mechanically more durable than any previously manufactured from pure rubber. Following the method of Day many manufacturers have employed these substitutes for the improvement of vulcanized rubber in wire covering, and have evaded the implication of dishonesty by applying to their products special trade names: Nigrite, Voltite, Bitite, etc., some of which materials contain oxidized oils, special varieties of rubber shoddy, petroleum residuum, ozocerite and special grades of bitumen, all mixed with rubber and subsequently vulcanized.

Pure rubber without admixture of sulphur and vulcanization is rarely employed as an entire insulator for a wire, though one of the best of the rubber cores was formerly manufactured by covering the wire directly with a taping of pure rubber surrounded by a layer of rubber compound containing no sulphur, and finally protected from external influence by a vulcanized sheath. This wire is generally known as Hooper's core and was invented as early as 1860 by M. W. Hooper, of England, the construction aiming to remove the sulphur so far from the copper wire by the interposition of two unvulcanized layers that no action would take place between the material of the wire and the sulphur of the outer covering. This method of protecting the

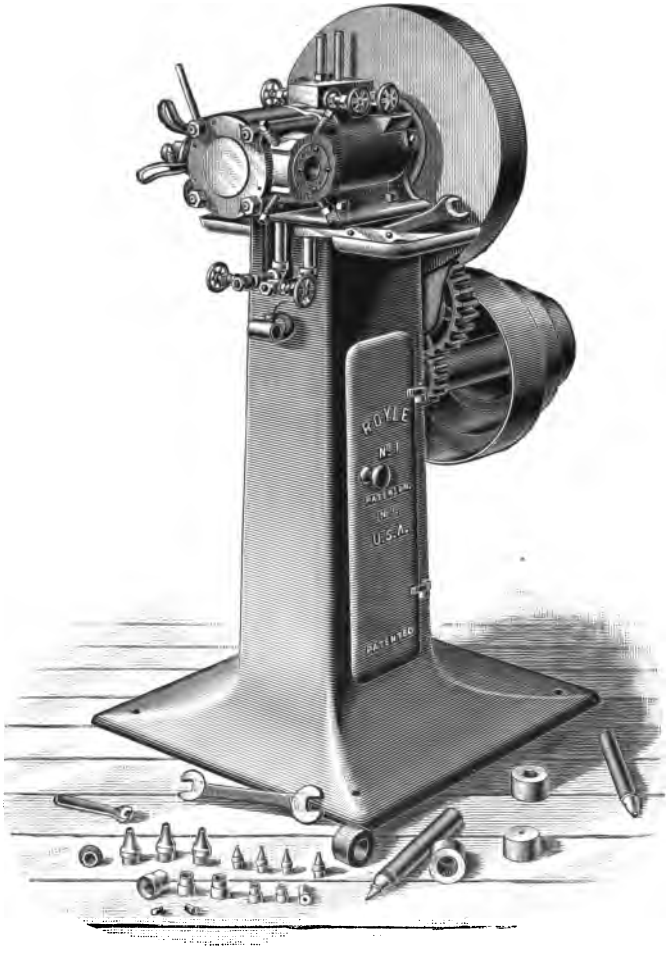
copper is exceedingly expensive and presents no distinct advantages over the more modern process of tinning the copper wire, a device which is found to effectually protect it against the action of the sulphur. Some manufacturers, however, continue to employ an inner coating of unvulcanized rubber compound, and, indeed, some such method seems necessary with very small wires, in which case the tinning does not grant perfect immunity from the action of the sulphur. It is also argued in favor of this method of manufacture that the unvulcanized inner coating forms an additional insulation, reducing the possibility of mechanical defects in wires covered with a single coating, but this seems to be a doubtful claim on account of the fact that an unvulcanized rubber compound will absorb water quite readily even were it possible to assume that the compound itself did not retain water after the wire had been vulcanized in a steam bath. Considerable amounts of water have, in fact, been found by the author in such a coating where the coating by itself had been removed and carefully dessicated. A better method of protecting the wire against the action of sulphur and at the same time of obtaining a high value of insulation seems to consist in coating the wire with more than a single covering of rubber compound capable of being vulcanized, the mixing being so carried out that those toward the inside are prepared with a smaller amount of sulphur than the outside coatings destined to withstand mechanical strains.

Before vulcanization, rubber compounds are comparatively inelastic and very plastic, readily united by pressure across freshly cut surfaces. Taking advantage of these facts two general methods are employed in covering wires with rubber for the purpose of insulation. In the first method the rubber compound which has been thoroughly mixed by the grinding rolls is passed through a series of calender rolls which deliver the product in a thin uniform sheet. These rubber sheets are then cut into strips of such a width as to easily surround the wires to be insulated and applied to the wire by a machine which guides the rubber strip around the wire and afterward consolidates it into a tube by pressure from a pair of grooved wheels furnished on one side with a cutting edge destined to remove any excess of rubber compound occasioned by an extra width of the strip. Provided the surfaces joined together are clean, this method of covering

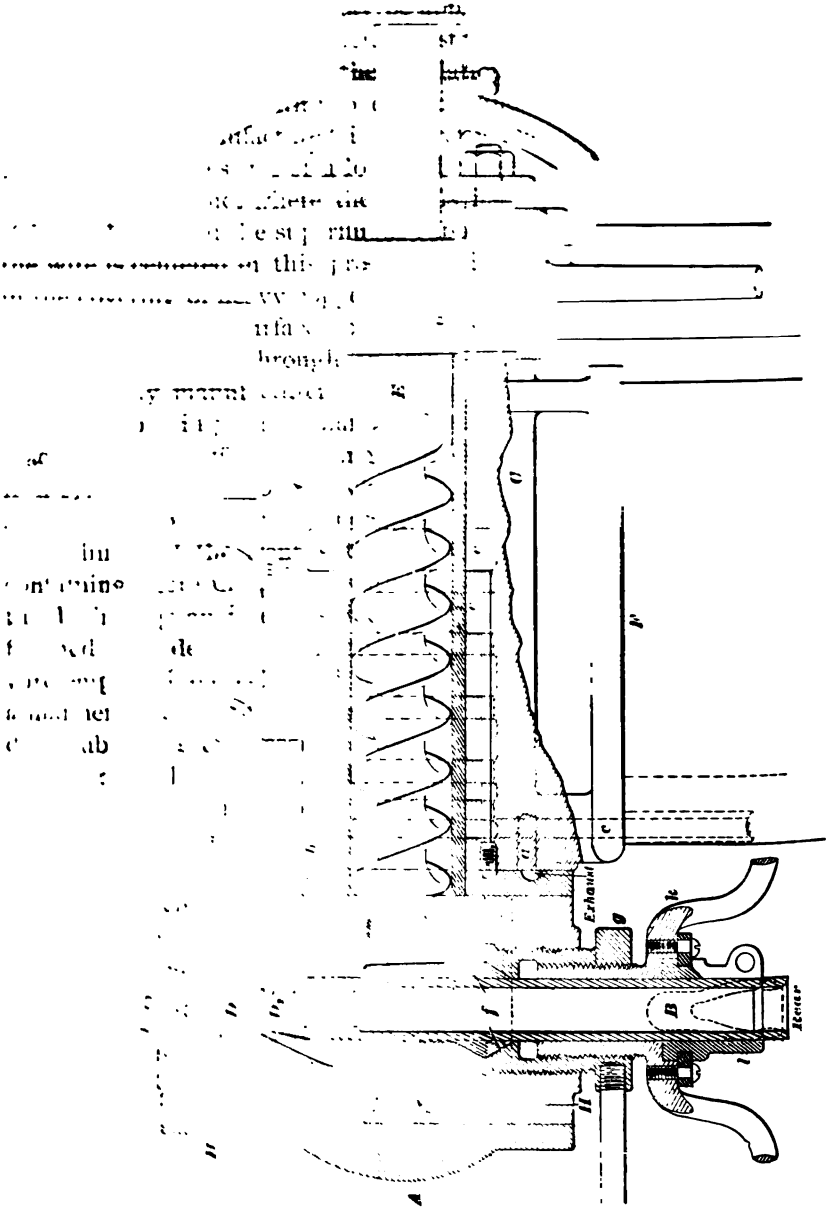
produces a continuous insulating tube, and has the additional advantage that the rubber may be applied at the temperature of the workroom when it is sufficiently strong to maintain the wire accurately in the center of the insulation, an object difficult to attain when covering with rubber compounds at a higher temperature. Wires manufactured in this way may be readily distinguished by the presence of a longitudinal seam which remains in the finished product where the wheels have joined together the strips and removed the superfluous rubber. The ease with which the wire is centered in this process attains particular importance in the covering of heavy copper wires. The defect of the process is that unless the surfaces of the rubber are absolutely clean minute leaks occur through an imperfect union, and in consequence many manufacturers prefer to employ a tubing machine for wire covering, particularly in small sizes. This tubing machine as manufactured in this country consists of a hollow iron cylinder with a long pitch screw revolving on an axis parallel to the axis of the cylinder and inclosed entirely within it, the cylinder at the front of the screw terminating in a chamber containing a core and pierced with an opening where a die is held, the die having an internal diameter equal to the diameter of the finished wire desired, while the core is bored out to the size of wire employed and held so that it projects within the die in such a manner that when the rubber is forced between the core and the die a tube is formed closely surrounding the wire with an external diameter equal to the internal diameter of the hole in the die. In such a machine the rubber is fed at the back of the screw which carries it forward into the chamber containing the core and die until in due course it is forced out as a tube, carrying the wire with it held in the center. This machine, on account of its method of operation, applies a very considerable amount of pressure to the rubber compound as it is molded around the wire and makes a very compact and continuous coating; it is, however, impossible to force the rubber through a machine of this character unless the temperature is raised slightly above the temperature of the air, and where the wire is heavy and the completed product as delivered from the machine is not completely cooled before being reeled up, serious decentering of the wire within the core occasionally takes place, although, as we have said, this is not a difficulty to be feared with small wires, nor is it likely to occur when the



Guiders, guider-tube and reducers.



ROYLE SIDE-DELIVERY INSULATING MACHINE.



PLAN OF ROYLE SIDE-DELIVERY INSULATING MACHINE.

rubber is applied in a series of thin coatings in place of a single thick layer.

However the rubber covering may be applied to the wire before final vulcanization, it is necessary to give some external support to the rubber in order to prevent it from swelling up and becoming porous during the process of vulcanization. With small wires sufficient support is provided by coiling the wires helically within a pan and packing closely in powdered chalk or talc, but for larger sizes it has been found necessary to cover the wire with either a tape or braid closely applied. One manufacturer who applies rubber in strips by the means of wheels as described above surrounds the completed wire with a coating of tin foil which is removed after vulcanization; as applied in this manner a thoroughly compact vulcanized rubber is obtained, though there is a certain amount of danger, in removing the tin foil, of cutting the insulation and making defects which must be repaired when the wire is finally tested for insulation resistance before shipment.

The final operation to which rubber-covered wires are subjected, repeatedly referred to under the name of vulcanization, consists in effecting a combination between the rubber and the sulphur, with which it has been mixed, under the influence of heat, at temperatures between 120° and 140° Cent., continued for periods varying from three-quarters of an hour to five or six hours, the variation in the time and temperature being the means of rendering the complete material of any required hardness and elasticity within limits determined by the quantity of sulphur present. For ordinary wires the application of a temperature about 130° Cent., during a period of one hour, may be considered as the average practice; a lighter vulcanization can be used only when the completed rubber is designed to have properties but slightly different from those of pure gum, while the higher temperatures in connection with larger amounts of sulphur are employed when it is desired to produce an inelastic solid material such as is generally called ebonite or vulcanite. Some manufacturers prefer to use for vulcanizing chambers hot ovens warmed by steam coils, and for a long time it was thought that this was the only method safe to use in the manufacture of a wire coating to have a high insulation resistance, but more recent experiments have proved that the presence of dry steam is not

only not injurious to the insulating properties of rubber compounds, but that it even tends to make the rubber coating more solid and more flexible. In consequence, most manufacturers now perform vulcanization in large iron tanks, closed with a removable cover, into which dry steam is admitted, directly surrounding the rubber articles to be vulcanized. A proper union between the sulphur and the rubber will not take place if there is any considerable amount of moisture present in the steam, and especially if water of condensation remains within the vulcanizing tanks, and, in consequence, rubber wires are occasionally found which show imperfect vulcanization in certain parts of the coil, where the wire, during the heating process, has lain in water condensed within the vulcanizer and not properly drained away, a defect which is often difficult to discover, even on an immersion test, but which unfailingly renders the rubber liable to oxidation when exposed to the air or sunlight. The combination between rubber and sulphur seems to be only partially of the nature of chemical composition, and, indeed, if vulcanized rubber is to be considered as a definite chemical compound, the combination is not only unstable but also difficult to form completely, and in consequence thin rubber, when examined under a microscope, will be found to separate into crystals of sulphur and particles of gum as it is subjected to atmospheric influences. Furthermore, subsequent high heating will always increase the vulcanization of elastic rubber and rubber compounds, rendering them inelastic and brittle.

These peculiarities vary at different times and with different compounds, so that the complete test of a rubber-coated wire includes not only measurements of the insulation resistance when immersed in water, but also mechanical tests as complete as is possible, but particularly a test to determine the action of the atmosphere on a strained and deformed portion of the rubber covering, such as may be obtained by winding a wire about its own diameter and leaving it for a considerable period of time in a position exposed to all possible atmospheric influences.

In order to protect such an insulated wire from the effects of frost and sunlight as far as would be possible, most manufacturers prefer to finish the outside with a braided or taped covering with a polished asphaltum surface, such as has been described in the

manufacture of weatherproof wire, this surface being called by rubber manufacturers a "slicker."

The reasons for the nonuniformity in weight per foot and thickness, which render the sale of weatherproof wire by the pound advisable, do not exist in the case of wires insulated with rubber coatings, and in consequence they are sold by the foot, reference being made at the same time to the thickness of the insulation and to its specific insulation resistance, though we should not confuse the value of the insulation resistance in megohms with the insulating power of a wire in service, since the loss of energy through the insulation is at all times an inappreciable amount of the total quantity of energy transmitted, and in consequence we must consider the mechanical properties and power to remain constant of much greater importance than the tested value of any particular insulation. It is for this reason that we have called attention to the fact that the purest rubbers are not always the best insulators, since it is found that the mechanical properties of rubber wires are improved by the presence of certain rubber substitutes, though it may be also true that these substances reduce the specific resistance of the insulating material.

The thickness of insulation necessary with rubber-coated wires to withstand different electric pressures has been much discussed by the various boards of trade and underwriters' associations of this and other countries, but no definite conclusions have been reached or rules laid down beyond the arbitrary instructions of the British Board of Trade, which state that all conductors carrying current at less than two thousand volts shall be covered with an insulation at least one-tenth of an inch thick, and that the insulations for heavy voltages shall be measured in inches of thickness by the quotient expressed in dividing the voltage by twenty thousand. This rule is entirely an arbitrary one and imposes a considerable tax on distribution at low voltages, besides rendering the insulation of a small wire unnecessarily bulky. As a substitute it has been proposed that the insulation should not be less than one-half the diameter of the wire where the voltage does not exceed two thousand, proportionate increase being made for higher voltages, though this also takes no account of the actual factor of safety in any particular installation. We are beginning now to recognize the fact that the thickness of

insulation for any wire may be obtained by breaking-down trials, allowing a satisfactory factor of safety in the case of each insulation thickness. Wire coated with a rubber coating three-sixteenths of an inch thick will not be pierced with a voltage smaller than about fifteen thousand, and we would accordingly consider that one-sixteenth of an inch of rubber will give a factor of safety of five for three thousand volts of strain, though without further experiment it is not possible to state distinctly that the protection offered by an insulation varies directly with its thickness. Indeed, other trials involving a piercing of dielectrics seem to indicate that their resisting power is proportioned more nearly to the square than to the first power of their thickness. Though in insulating wires used for transmitting alternating currents it is unsafe to assume that the resisting power varies more rapidly than the first power of the thickness on account of a general uncertainty concerning the relation of maximum value of the electromotive force to its average value on account of great variations in the forms of different electromotive force curves generated by commercial machines.

In the pages which have preceded, in a series the general types of insulators have been described which are regularly employed for protecting wires, and while the method of manufacture is the same for each material in every form of use, special combinations in construction and in manufacturing methods have been introduced in order to adapt these general insulating plans to definite and particular requirements — the products of these various specialized processes being known by the title of the department of construction in which they are to be employed; as we may speak of overhead line wires, underground cables, aërial cables and submarine cables without necessarily indicating wires different in construction. For use in overhead lines any one of the insulated wires which we have described may be employed without further modification, excepting only gutta-percha wire, which is much too readily influenced by the oxidizing action of sunlight to be employed for such purposes. The manufacture of the overhead line conductor has therefore been already completely discussed; but for use underground and for submarine work these wires must all be protected in special ways in order to prevent injurious mechanical and chemical action upon the insulators.

For general use in this country, in building underground lines highly insulated cables have been employed, the insulating material being further protected by a covering of lead pipe. This system of cable construction was one of the very first attempted for the construction of telegraph lines; indeed, we find that in 1838, the year following the introduction of the telegraph into England, an English patent was issued to W. T. Cook in which he describes his conductors "as laid within solid lead pipes." In 1845 two further patents were issued: the first, to Wheatstone and Cook, in which the modern method of lead-incasing cables with a lead pipe machine is described; the second, issued to W. Young and A. McNair, specifies the same system of lead-incasing and according to the same processes.

Lead cables were laid in the streets of London in 1844, identical in construction with those made at the present time.* Indeed, the various early inventors described all possible processes of covering cables with lead: by drawing them into pipes, by forming the lead pipe around the cable, by taping the lead spirally or longitudinally and soldering the joints, by drawing down a large lead pipe tightly over the cable by the means of dies or rollers. We see, therefore, that the construction of a lead-inclosed cable was adopted from the earliest times and that this system has had an opportunity of an exceedingly long trial. The necessity for some sort of protection to insulated wires laid underground was noticed from the first on account of the very injurious action of the various acids and solids found in the soil, and particularly the injurious activity of acetic acid. The different acids and oils destructive to insulation are so varied in character and action that no effectual compound has been found which is capable of withstanding their influences. In consequence, wherever an underground cable is insulated with any nonconducting material the permanence of the insulator depends upon the existence of a hermetically sealed sheath. Further, on account of the fact that this sheath must be perfectly made and continuous for the whole length of the conductor, it is possible to employ in the insulating of underground conductors materials which, while high in insulating property, are readily saturated by moisture and which cannot be relied upon as insulators without the inclosing sheaths; and in this form of construction much use has been made of

* "Manual of Telephony," Preece & Stubbs, page 451.

[illegible]

[illegible] exactly similar [illegible] certained as use. [illegible] construction [illegible] great pressures necessary [illegible] systems of machinery [illegible] the condition of the [illegible] and into the cable. In [illegible] employed in this country [illegible] immersion; the cable and [illegible] increasing [illegible] the insulation [illegible] and, in consequence, [illegible] considered necessary. [illegible] sonantium or pitch [illegible]

[illegible] either cold or [illegible] point. When manufactured [illegible] lead [illegible] fortunately we can [illegible] manufactured in this manner [illegible] — [illegible] time to its [illegible] temperature of solidification. [illegible] will take a [illegible] that at the temperature [illegible] which has moved [illegible] would be solidified [illegible] which cannot again be melted [illegible] presumes assertion as to oxidation [illegible] alter in name, but the [illegible] combined into a solid mass disproves [illegible] that it be temperature of solidification [illegible] that it will not withstand even a [illegible] the cable is not injured until after solidification has taken place [illegible] malleable, and, indeed, may be readily worked without further heat under the influence of a heavy pressure. These properties, as we have said, insure the perfection

of forced lead pipe, since it is impossible to make a pipe at all at a temperature higher than that at which the lead becomes malleable when it is also readily weldable. No theory is given here, but rather the actual experience obtained from the practice of lead pipe manufacturers who find their pipes to be perfect unless foreign matters become mixed with the molten lead in the machine cylinders.

The presses used in lead-incasing cables consists of a pair of heavy steel castings strongly bolted together and locked one above the other, the lower casting being bored out to a diameter of from fifteen to twenty inches and lined with copper, thus forming the cylinder of a hydraulic press. The ram of this press carries on its head a steel chamber called a "core box," containing a core and die of exactly the same nature as the core and die already described for the manufacture of rubber-covered wires. Above this chamber is bolted a lead-containing cylinder opening into the core box. This cylinder is open at the top, the lead ram being bolted to the upper steel casting of the press, the lead rams and cylinders used varying in diameter from five to eight inches, depending on the size of the lead pipe to be formed. In operation the hydraulic ram is lowered as far as possible, carrying with it the core box and the lead cylinder, till a charge of lead can be run into the lead cylinder ; the pressure is then applied and the lead cylinder raised until its ram is brought down on the top of the molten lead with a slight pressure, where it remains until the lead has become solidified, when the hydraulic pressure is increased to between six and eight thousand pounds per square inch, equivalent to a pressure on the lead of between fifty and sixty thousand pounds per square inch, when the solid lead flows between the core and die and passes out from the machine as a continuous pipe. As soon as the entire charge within the cylinder has been forced out, the lead cylinder and water ram are lowered as before, withdrawing the lead plunger and allowing a second charge of lead to be run into the lead cylinder, which unites with the portion of the first charge remaining within the core box, and, as pressure is subsequently again applied, the pipe is delivered without the least break at the point of union between the two charges of lead. This operation may be repeated as many times as will be necessary to cover a particular length of cable, as it is found that cold lead unites into a solid mass under a pressure

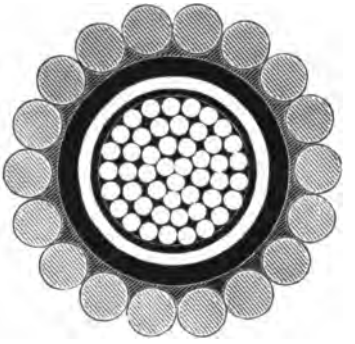
of thirteen tons per square inch and flows at a pressure of thirty-three tons per square inch.*

From this it is seen that lead may be worked and will form a continuous pipe at any desired temperature below its melting point, and that this operation does not necessarily injure any insulating material by reason of the high temperature necessary in the operation, nor is more than a single coating necessary for a perfectly solid pipe.

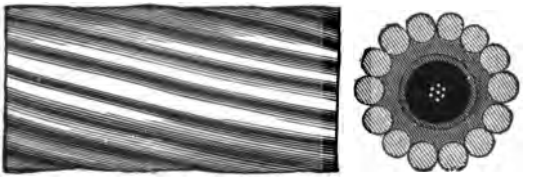
Gutta-percha wires are rarely lead-incased by this process, but such cables are made having india rubber as an insulation, and, as we have stated, fiber and paper are also used. While these fibrous coverings are similar in character to the weather-proof wires we have already described, certain essential modifications are made in them when they are employed for cables. In the first place, as no particular mechanical strength is required for the insulating material, yarns are rarely braided upon the wires, but they are more generally applied by the cheaper process of winding, larger diameters of yarn being also employed, the general practice being to apply at least one-sixteenth of an inch of insulation in a single winding. In order to obtain the high values of insulation required in cable working, these yarns are applied without compound and thoroughly desiccated in ovens before saturation is effected.

For the purpose of saturation, waxes rendered liquid by solvents are not used, but, on the contrary, materials softened by heat are invariably employed. Any wax or gum capable of being rendered so liquid by heat that it will saturate the yarn may be employed; but in this country use has only been made of paraffin, ozocerite, asphaltum, petroleum residuum and rosin, though sometimes manufacturers prefer to soften these materials by an oil admixture rather than to use them alone; rosin with cotton seed oil or rosin with rosin oil being the favorites. The values of these oils consist in their power of making the waxes viscous at all temperatures and allowing any cracks made in the cable under the lead covering to be naturally healed. Should such a crack be formed within the insulation of any lead-incased cable a partial vacuum of comparatively high conducting power is obtained and the insulating power much diminished. This fact, perhaps,

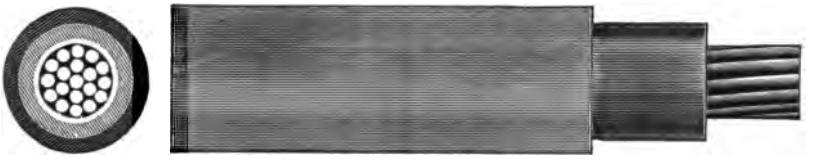
* See "Experiments," by Professor Spring, of Liege; "Mixed Metals," A. H. Hiorns, page 73.



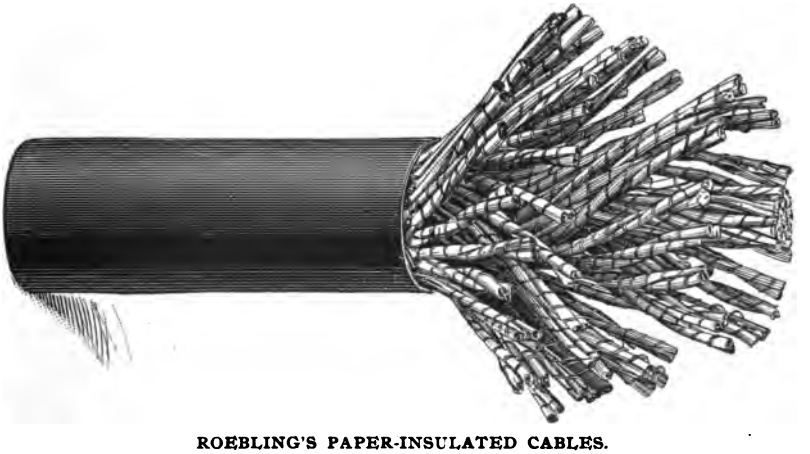
BISHOP-HOOPER TYPE OF POWER FEEDER CABLE.



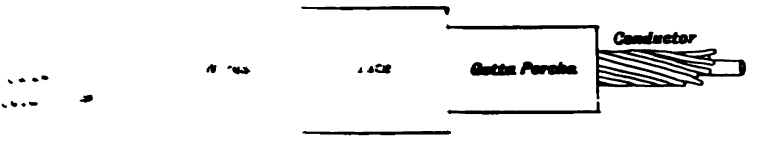
BISHOP OCEAN CABLE, WITHOUT WRAPPING OF JUTE.



BISHOP LEAD-ENCASED CABLE, WITH WHITE CORE, RUBBER INSULATION.



ROEBLING'S PAPER-INSULATED CABLES.



SUBMARINE TELEGRAPH CABLE.

[illegible] the curious fact that such insulation seems to possess [illegible] which cannot be greatly increased by an [illegible] the reason being that all fibrous materials [illegible] saturated in a vacuum, [illegible] leaving vacuous spaces which by [illegible] the air pressure within them determines the [illegible] of the covering materials.

[illegible] cables and yarn-covered cables for special [illegible] have been employed under a lead sheath without auxil- [illegible] and particularly for telephone purposes [illegible] which is a specific inductive capacity can thus be [illegible] such construction is admirable, but where high poten- [illegible] these dry materials have not been found [illegible] the same substances when saturated. It seems [illegible] paper or dry cotton, giving a much higher insu- [illegible] than the same materials saturated, should be [illegible] by the application of a high electromotive [illegible] when we consider that such cables are generally lead- [illegible] from the drying ovens we see that at normal [illegible] the air pressure within them is low, approaching [illegible] a Crookes' tube, and also we know that the loose free [illegible] the insulation may carry a charge from the wire to the [illegible] exactly as though they were a series of suspended pith [illegible] Taken together, these two facts will explain the fact [illegible] the exclusive use of saturated fibers for high potential [illegible]

[illegible] for suspension in the air have sometimes been protected [illegible] by a wrapping of rubber laid either spirally or with a [illegible] seam, but in almost all cases lead-incased cables are

now used for carrying electric light, telephone and telegraph currents, whether overhead or underground. We may tabulate such cables according to the following plan:

Cables.	No. of Conductors.	Character of Conductor.	Size of Individual Wires.
Electric light less than 500 volts	Single.	Stranded.	No. 10 B. & S. or smaller.
Arc lighting	Single.	Solid.	No. 6 or 4 B. & S.
High tension power transmission	Single, concentric or duplex.	Stranded.	No. 10 B. & S. or smaller.
Telegraph, submarine	Multiple wires.	Stranded.	No. 19 B. & S.
Telegraph, short cables	Multiple wires.	Solid.	No. 14 B. & S.
Telephone	Multiple wires.	Solid wire.	No. 18 or 19 B. & S.

	Thickness of Insulation.				Thickness of Lead.
	Rubber.	Saturated Fiber.	Saturated Paper.	Dry Paper.	
	inch.	inch.	inch.	inch.	inch.
Electric light less than 500 volts	$\frac{3}{32}$	$\frac{6}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{1}{16}$ to $\frac{1}{10}$
Arc lighting	$\frac{5}{32}$ to $\frac{8}{32}$	$\frac{8}{32}$	$\frac{8}{32}$	$\frac{8}{32}$	$\frac{1}{10}$
High tension power transmission	$\frac{5}{32}$ to $\frac{8}{32}$	$\frac{8}{32}$	$\frac{8}{32}$	$\frac{8}{32}$	$\frac{1}{10}$
Telegraph	$\frac{8}{32}$	$\frac{8}{32}$	$\frac{8}{32}$	$\frac{8}{32}$	$\frac{8}{32}$
Telephone	$\frac{1}{16}$	$\frac{8}{64}$	$\frac{8}{64}$	$\frac{8}{64}$	$\frac{1}{10}$ to $\frac{1}{8}$

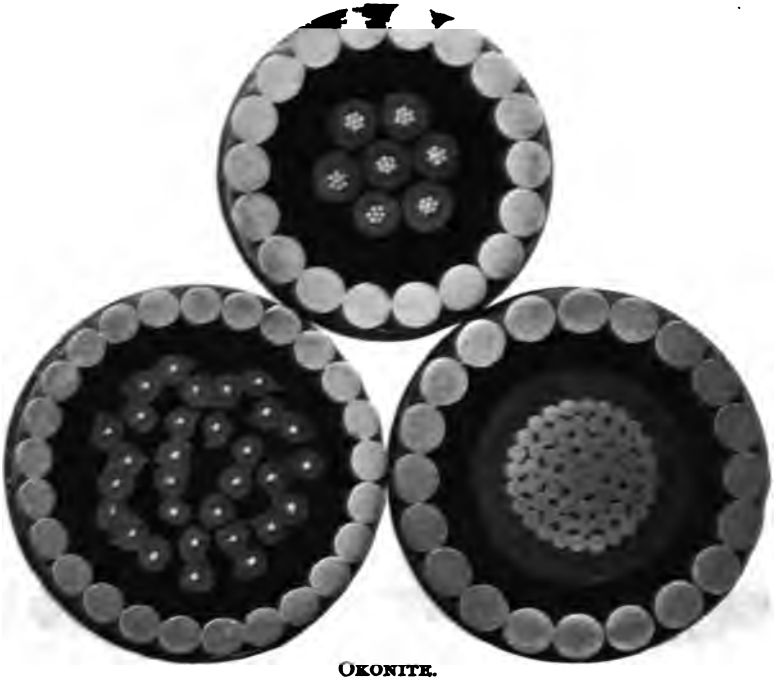
It is not to be understood that these dimensions are in any sense exact, as will be at once apparent to a practical engineer, but the principal difference between the various types of cables are here sufficiently well laid down to enable a comparison of the various systems of construction. In the case of paper-insulated electric light, telephone and telegraph cables we find the paper sometimes applied spirally without the use of any binder; but where a low specific inductive capacity is sought in telephone working the paper is laid upon the wire longitudinally and held in place by a spiral wrapping of cotton yarn, a system of construction which is found to give the proper distance between the wires with the use of a minimum amount of paper and a maximum amount of air in the insulation. Outside the lead of cables designed for use underground, some protecting material is gener-

[illegible] or tape, thoroughly [illegible] is necessary on [illegible] becomes easily corroded under [illegible] present in the soil and always [illegible] power is also given [illegible] of three per cent of tin in [illegible] the lead coming from the [illegible] workmen, even when they are [illegible] where they are paid upon [illegible] Argentiferous lead also resists [illegible] for a long time, but under present [illegible] is rarely found in the market.*

[illegible] poles have been sometimes employed [illegible] two miles; but as the protection [illegible] not sufficient to withstand serious [illegible] weight of leaded cable is very great, [illegible] beyond short distances, and only in [illegible] type of cable of low static capacity [illegible] be efficiently protected in any other [illegible] of submarine cable for bays and [illegible] more rubber-covered stranded wires [illegible] protected by an external bedding of [illegible] number of heavy iron wires are spi- [illegible] armor, the size and number of iron [illegible] upon the diameter of the cable and [illegible] from ships' anchors or keels. Tarred [illegible] bedding for the iron wires, but it [illegible] of its semi-insulating properties [illegible] nity location, while the tanning [illegible] against decay. The common type [illegible] country contains from three to [illegible] coating about a quarter [illegible] covered with galvanized iron either [illegible] where there is great likelihood [illegible] iron wire is increased in size up [illegible] cables are generally laid with- [illegible] beyond a heavy coating of [illegible] used in ocean transmission [illegible] employed of the type called

[illegible] London, August 15, 1896.

AN OKONITE CABLE INSULATING MACHINE.



OKONITE.

Submarine Telegraph Cable,
7-Conductor.

15-Pair (30 Conductors Twisted)
Submarine Telephone Cable.

Submarine Feeder for
Electric Railway Circuits.

Hooper's Core, already described, but it is more usual to insulate seven strands of wire, varying from No. 22 to No. 19 B. & S., with three or four layers of gutta-percha, making the external diameter about from ¼ to ⅜ inch. This core being used singly and protected by a wrapping of tanned jute around which iron wires are spiralled in three sizes, depending upon the ultimate destination of the cables, the deep sea portions having an armor varying from eleven galvanized iron wires, each 143 mils in diameter, to ten wires, each 143 mils in diameter; the shallow water portions are armored with twelve wires, each 238 mils in diameter, the shore ends consisting of the lighter deep sea portion further armored with twelve strands of three wires, each 230 mils in diameter. In every case the armor wire is protected by two wrappings of jute yarn, impregnated with a material called

Clark's Compound, consisting of sixty parts of mineral pitch and asphaltum and forty parts of finely ground sand, this last covering being intended to protect the armor wires from the action of salts contained in the sea water and in the ocean bed where the cables lie, the deep sea cables being about from ⅞ to 1⅛ inches in diameter, the intermediate cables 1¾ and the shore ends 2½ inches in diameter. These specifications are greatly varied by different manufacturers and by the different requirements of insulation and static capacity demanded, some of the most recent cables having much heavier conductors and gutta-percha and a lighter armor for the portions lying in the deepest portions of the sea.

DRAWBAUGH COMPARISONS.

An interview with Mr. Bartlett, president of the Drawbaugh Telephone Company, in the New York *Herald*, October 18, 1896:

"The microphone covered by the Berliner patent was invented by Drawbaugh long prior to its invention by either Berliner or Edison.

"After the Supreme Court decision rendered in 1888 against the Drawbaugh Company by a vote of four to three, the government, upon examination of the evidence, and notwithstanding the Supreme Court decision, concluded that Drawbaugh did invent the telephone prior to Bell, and went into Court and moved to amend their bill of complaint in the suit against the Bell Company then pending, by setting up in said bill of complaint the additional fact that Drawbaugh and not Bell was the first inventor of the telephone and the one entitled to a patent.

"The Government has demonstrated this fact by the introduction of important and conclusive evidence not brought out in the first suit, which, *in the language of the Government counsel*, establishes overwhelmingly the priority of Drawbaugh's invention."

From the decision rendered September 29, 1896, of the United States Court of Appeals of the District of Columbia, which sustained the Patent Office in the rejection of the Drawbaugh Application:

"There is another principal ground acted upon in the Patent Office for the rejection of these claims, and that is abandonment by Drawbaugh. Upon the assumption that he may have made a patentable invention of a transmitter, as he now claims, that by his great delay and neglect in applying for a patent and allowing others to invent and occupy the field and expend their money and time in developing the business and establishing the use of the alleged invention he has forfeited and abandoned all claims to such invention if he ever had any in fact, and for that reason his claim should be rejected. If it were necessary to invoke this principle in order to dispose of this case we should not hesitate upon the facts disclosed to approve of the rulings of the officials of the Patent Office in this respect, but as we hold that Drawbaugh was never the inventor of the transmitter as now claimed by him, and as stated in his affidavits, prior to the dates given in the reference cited against him in the Patent Office, it is, therefore, unnecessary to test the decision of the case upon this objection."

EUROPEAN TELEPHONE STATISTICS FOR THE YEAR 1894.

BY FRANZ J. DOMMERQUE, M.E.

The following table is calculated from data furnished by the *Journal Télégraphique*. In most of the countries the telephone business is in the hands of the Government. In Germany, for instance, it is associated with the post and telegraph, and the three branches are under the same management, occupy the same buildings and thus effect considerable economy in the expense account. In some cases this did not allow of separating the expense for telephone service from the other items. The average length of subscriber's line was calculated with the assumption that all lines were grounded lines, which brings the figures somewhat high; but there will not be a material difference, only a small percentage of the lines on the continent being completely metallic at the end of 1894. The introduction of the electric railway necessarily means an increase in metallic telephone circuits. The conservative public has not yet become accustomed to calling by numbers, certainly the majority of the smaller exchanges call by name, which is possible, as the number of calls per subscriber per day is comparatively low. The cost of labor is made up from the salaries paid to managers, engineers, maintenance employes, workmen, operators and helpers. The cost of material given for Switzerland includes interest and depreciation on plant. The rest of the table is self-explanatory.

The data obtainable for Japan shows that in 1894, with four stations and 2,874 subscribers, 36,516 calls per day were averaged, which gives 12.7 calls per subscriber per day. The average length of subscribers' lines was 1.48 miles, the expense for labor per subscriber per year $8.14; and for material per subscriber $51.14, the latter figure probably including interest and depreciation, as well as money spent upon new installations commenced during the year 1894.

EUROPEAN TELEPHONE STATISTI

	Germany (Governmental)	Austria (Governmental)	Austria. Vienna Exchange Private Company.	Belgium. Governmental.	Belgium. Private Companies.
Number of installations	475	22[illegible]	1	12	3
Number of stations	30[illegible]	73[illegible]	1	35	4
Number of subscribers	78,52[illegible]	5,725	7,924	8,221	340
Number of public pay stations	470	220	16	104	2
Urban wire miles. Aerial: in service	84,521	5,116	4,471	12,045	335
Urban wire miles. Aerial: in reserve	1,722	162	.....	.....	37
Urban wire miles. Underground: in service	73,[illegible]5	.....	21,765	.....	.....
Urban wire miles. Underground: in reserve	4,47[illegible]	.....	.....	.....	.....
Number of toll lines. Grounded	902	.....	.....	.....	.....
Number of toll lines. Metallic	412	34	.....	80	.....
Number of long-distance lines	42	13	.....	7	.....
Toll and long-distance wire miles. Aerial	22,435	5,854	.....	6,853	.....
Toll and long-distance wire miles. Underground	5[illegible]	.....	.....	.....	.....
Toll and long-distance wire miles. Submarine	.....	.....	.....	.....	.....
Subscribers' calls per day	8[illegible],[illegible]3	39,721	115,685	47,917	228[illegible]
Calls per day between subscribers and pay stations	1,223	157	401	84.8	1.7[illegible]
Messenger messages per day	13.6	97.2	.....	.....	.....
Telegrams by telephone per day. Outgoing	1,855	759	.....	1,340	61.1
Telegrams by telephone per day. Incoming	1,064	976	.....	1,160	54.4
Total messages per day	332,973.6	42,700.2	116,086	50,501.8	345.2
Number of calls per subscriber per day	7.27	4.75	14.6	6.14	.....
Average length of subscriber's line in miles	.35	.90	3.30	1.44	.98
Annual expense for labor in dollars	.....	104,707.50	257,357.50	.....	1,248.00[illegible]
Annual expense for material in dollars	.....	13,[illegible].00		.....	1,219.37[illegible]
Cost of labor per subscriber per year in dollars	.....	13.40	29.89	.....	3.65[illegible]
Cost of material per subscriber per year in dollars	.....	1.40		.....	3.57[illegible]
Cost of labor per 1,000 messages in dollars	.....	7.52	5.63	.....	9.66[illegible]
Cost of material per 1,000 messages in dollars	.....	0.36		.....	9.68[illegible]

[illegible] per installation [illegible]

R THE YEAR 1894.

Governmental.	Hungary. Private Companies.	Holland. Private Companies.	Italy. Private Companies.	Luxembourg. Governmental.	Russia. Governmental.	Russia. Private Companies.	Sweden. Governmental.	Sweden. Private Companies.	Sweden. Citizens' Coöperative.	Switzerland. Governmental.
28	6	16	54	54	34	11	124	14	160	189
148	6	22	56	54	42	14	508	211	188	189
103	857	4,422	11,635	1,188	4,227	6,202	18,737	11,586	5,516	19,549
93	10	44	35	82	20	.....	.....	309	379	265
786	697	.....	12,185	457	5,929	11,118	13,867	10,194	6,694	17,803
.....	.....	.....	3,184	.....	240	1,764	.....	.....	.....	
.....	.....	.....	.....	.....	8	14	1,616	.....	.....	7,752
.....	.....	.....	.....	.....	6	2	.....	.....	.....	
31	.....	3	.....	83	19	.....	113	.....	.....	55
1	.....	24	.....	17	.....	.....	334	.....	.....	207
1	.....	.....	.....	.....	.....	.....	2	.....	.....	5
,072	.....	370	.....	1,128	489	.....	13,599	2,628	2,590	3,946
.....	.....		.....	.....	.....	.....	.....	.....	.....	
.....	.....		.....	.....	.....	.....	.....	.....	.....	
247	4,514	20,548	30,982	2,610	24,428	31,385	106,322	76,474	9,098	27,345
15.2	12.2	31.9	313	418	6.92	.....	.....	.....	.....	
.....	.....	.....	.....	.....	.....	.....	51	.....	.....	14.4
67	4 94	130	9.24	4.2	59.6	137	297	.....	.....	230
151	5.83	156	.03	2.9	43.1	101	291	.....	.....	272
480.2	4,536.97	20,865.9	31,304.27	2,658.9	24,537.62	31,623	106,961	76,474	9,098	27,861.4
6.16	5.3	4.94	2.7	2.23	5.8	5.1	5.7	6.6	1.6	1.42
1.06	.80	.....	1.04	.36	1.40	1.79	.82	.85	1.13	1.29
652.00	7,963.43	.....	45,572.03	20,268.40	92,583.20	.....	.....	.....	.....	107,797.86
119.50	9,456.60	.....	90,942.26		35,150.40	.....	359,241	.....	.....	433,355.88
6.25	9.18	.....	3.90	15.96	21.80	.....	.....	.....	.....	5.44
10.95	10.97	.....	7.79		8.28	.....	19.18	.....	.....	21.87
2.82	4.81	.....	3.98	20.85	10.33	.....	.....	.....	.....	10.59
4.93	5.71	.....	7.96		3.92	.....	9.20	.....	.....	42.61

WILLIAM EDWARD BURGESS.

At 3 o'clock on Tuesday morning, November 10, 1896, William Edward Burgess entered into a higher life, and on Wednesday evening his mortal remains were carried from his late residence in Park avenue, Chicago, and tenderly placed in the bosom of mother earth within the portals of Rose Hill Cemetery.

Born in Yorkshire, England, May 22, 1868, he received a thorough education in the higher English schools, and then entered the service of Willans & Robinson, the well-known engine builders, where he remained for a period of nearly seven years. While receiving his technical training, he also discharged the duties of private secretary to the late P. W. Willans, winning the highest confidence and enjoying a close intimacy rich in its

broadening influence on his ripening nature. Early in 1893 Mr. Burgess brought to Chicago the exhibits made by Willans & Robinson at the World's Fair, supervised the erection of the various engines, had entire charge of these exhibits, and at the close of the Exposition dismantled and reshipped to England what had not been disposed of in this country.

In November, 1893, after corresponding with Willans & Robinson, Mr. Burgess entered the service of the M. C. Bullock Manufacturing Company, of Chicago, who had secured the right to build the engine in this country. Here his official title was that of consulting engineer, yet he had entire charge of the Willans engine department of these works, designed all of the engines, and, in conjunction with the electrical engineers of the respective manufacturing companies supplying the electrical machinery, planned the arrangement and supervised the erection of the engines and generators in the important installation at the Pabst plant in Milwaukee, the street railway plant in Terre Haute, the Hyde Park plant in Chicago, and others.

When stricken with the typhoid fever which ended his earthly career, he was engaged on the Englewood & Chicago Street Railway Company's plant at Eighty-seventh street and Loomis avenue, Chicago, a full description of the technical features of which he intended to submit as a contribution to the proceedings of the Institute of Civil Engineers of England, of which he was a loyal member.

Mr. Burgess was not only a first-class mechanical engineer, but possessed a practical knowledge of the modern principles of hydraulic, steam, electrical and civil engineering, and was often called in consultation where important problems in these various branches of engineering work had to be solved. As an accomplished draftsman with artistic inclinations, he won one or more prizes for artistic sketches, quickly produced without apparent effort.

In February, 1895, he was joined in marriage to Miss Wickersham, of Chicago, and his home life was always a joyous and enviable one. Well informed on the current topics of the day, he was ever a pleasant companion and a charming conversationalist. A close student of important questions, once he had mastered a subject he held decided views that time would prove to be the right ones. His decided personality and his achievements made

him prominent in the circle of his acquaintance, while his cheerful and kindly disposition endeared him to his associates. Thus his death brought sorrow to many.

His last contribution to ELECTRICAL ENGINEERING, "Superheated Steam," which was the opening article in the November number of our magazine, was to have been the first of six or more papers on this important subject, which is attracting so much attention both in this country and in England. But illness prevented the completion of the remaining sections — a direct loss to the engineering fraternity, for he had gathered the results of wide experience rich in practical data.

In July, 1894, under the title of "The Direct-Coupling of Arc Light Dynamos," Mr. Burgess gave the readers of ELECTRICAL ENGINEERING a clear presentation of the advantages of the various methods of driving dynamos — from the engine point of view, and the peculiar advantages accruing from the use of the direct-coupled plant.

His contribution on the "Economical Limit of Boiler Pressures for Power Plants" attracted the attention of large users of steam everywhere, for he clearly portrayed how it would be possible by combination with the engine curve to determine the most economical pressure at which to work under any given set of conditions, if reliable loss curves could be obtained for both steam pipes and boilers at various pressures.

In ELECTRICAL ENGINEERING for February, 1895, Mr. Burgess gave some interesting details of the exhaustive trials the results from which are embodied in the Willans Law. Mr. Burgess was his private assistant at the time the idea first occurred to Mr. Willans that the total steam consumption of an engine would plot as a straight line, and when the results were laid before the Institute of Civil Engineers, Professor Kennedy said: "It was astonishing, if not even humiliating, to think how long this thing had been laying under one's eyes, and yet had not been seen. It had been customary to plot curves per indicated horse-power hour without taking the trouble to plot the actual observed quantity — the weight of water used per hour. Thus many things have escaped notice that would otherwise have been revealed."

FRED DE LAND.

METHODS OF FUEL TESTING.*

BY ARTHUR V. ABBOTT, C.E., AND FRANZ J. DOMMERQUE, M.E.

(*Continued from page 302.*)

While the method of the "bomb calorimeter" may be employed to determine the fuel value of gaseous combustibles, it presents the difficulty of requiring a compression arrangement whereby a sufficient quantity of the gas to be assayed may be forced into the combustion chamber, otherwise so small a quantity of fuel is employed as to give rise to serious errors. The

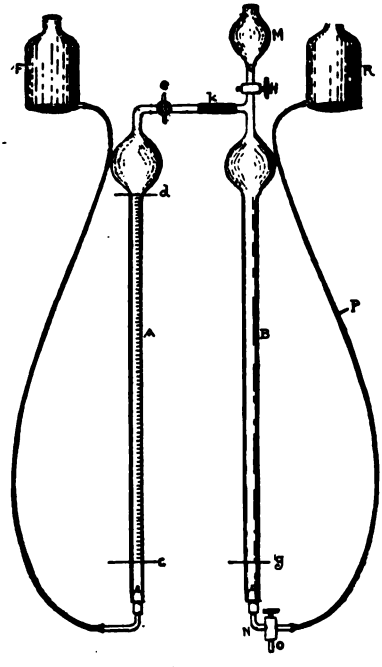


FIG. 4.

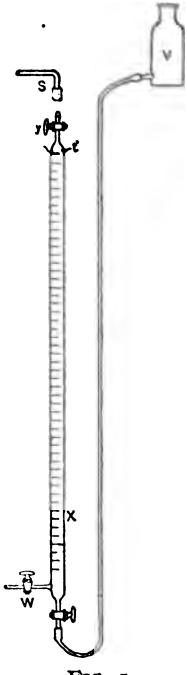


FIG. 5.

chemical determination of the constituents of fuel gas is relatively so easy compared with corresponding essays upon combustible

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solids and liquids that it is more customary to resort to the analytical method than to the calorimetric one for the purpose of determining the calorific power of gases.

The apparatus required is very simple, many approved designs being in common use. That devised by Elliott presents a maximum of advantages for analyses of reasonable accuracy and is illustrated in Fig. 4.

A measuring tube *A* contains precisely 100 c. c. between the zero point at *C* and the mark *d*, near the stop cock *e*. Between these two points the tube is graduated into divisions of 0.1 c. c. At the lower end, the tube is closed by a cork, bored to admit a piece of glass tubing, which connects it by rubber tubing to the outlet tube of the bottle, *F*, whose shape is similar to that of an aspirating bottle. The upper portion of *A* is a thick-walled capillary, bending at right angles to the wide part of *A*, provided with the stop-cock *e*, in the horizontal portion. The tube *B* holds 120 c. c. between the stop-cock *H* and the mark *g*. The capillary tube proceeds from the upper part, just below *H*, forming a right angle with the stem *B*. With a short piece of rubber tube, *k*, the two tubes *A* and *B* are joined. The thick-walled capillary tube tapers externally above the stop-cock *H*, and is made to fit into the funnel-shaped vessel *M*, which contains 25 c. c., to a mark near its top, when fitted onto the ground top of *B*. The lower end of *B* is fitted with a perforated cork, through which passes the glass tube *N*, having on its horizontal arm the three-way stop-cock *O*. *N* is joined to the bottle *R*, which is similar to *F*, by the rubber tube *P*. The arrangement of the stop-cock *O* is such as to give either a free passage between *N* and *P* or a passage between one of these and the outside air, through an opening in the bottom of the stem.

The bottles *R* and *F* are filled with water, by means of which the tubes *A* and *B* which have been connected prior to this, are filled. This being done, the cocks *H* and *e* are closed and *M* removed. The top *B* is then connected to a vessel containing the gas for analysis. The cock *H* is opened and the bottle *R* is lowered. The gas is then drawn into *B*, *H* being closed, when the gas reaches *g*. Then *R* is raised, *F* lowered, the cock *e* opened, and the gas drawn over into *A*. The surface of the water in *F* and the zero mark *C* are brought on a level, the water in *A* being brought to the same mark by raising or lowering *R*. The stop-

cock *e* is shut, and the tube *A* contains exactly 100 c. c. of gas, at the atmospheric temperature and pressure. The gas which remains in *B* is expelled through *H* and the funnel *M* fitted to the top of the tube. The sample of gas in *A* is drawn over into *B* by raising *F*, lowering *R*, and opening *e*, *e* being closed as soon as all the gas has passed over. The funnel *M* is filled with a solution of caustic potash until it reaches the mark. The water level in *B* is depressed as much as possible by lowering *R* and the stop-cock *O* is then set to shut off the tube *B*. By opening *H*, the potash is slowly run from *M* into *B*, a new supply of which may be introduced to *M* in case absorption seems to be very great. Full ten minutes should be allowed for the absorption. As soon as this process is complete the gas is passed back to *A* and the volume measured. The difference between the present volume and the previous volume is the carbon dioxide absorbed. The gas is then drawn back to *B* and a solution of pyrogallic acid introduced through *M*, in the same way as that employed for the caustic potash, and followed by a slight excess of caustic potash. The pyrogallic acid absorbs the oxygen, requiring about twenty minutes, then the gas is run back to *A* and another measurement taken. The loss in volume between this and the last measurement, the atmospheric conditions being the same, represents the volume of oxygen. After washing the tube *B* very thoroughly with water through *M*, it is refilled with clean water. The gas is then run over in a similar manner as before, and bromine water introduced through *M* to absorb the hydrocarbons contained in the gas. Sufficiently concentrated bromine water must be used so that bromine vapor will distinctly tinge the gas in *B*, care being taken that the vapor does not cause sufficient pressure to drive a portion of the gas out when *H* is opened. To avoid this, *R* may be lowered, and *O* opened, so that the pressure in *B* is slightly reduced when *H* is opened. After allowing about ten minutes for absorption, *H* should be opened and dilute solution of caustic potash admitted from *M* in order to absorb the bromine vapor. The gas is then run back to *A* and measured. The diminution since the last measurement represents the volume of "hydrocarbons" in the gas. Again, the tube *B* is washed out and refilled with water; the gas is drawn over to *B* and solution of cuprous chloride in hydrochloric acid to absorb carbon monoxide slowly introduced through *M*, the water at the lower part of *B* being run

out through *O* until it is entirely substituted by cuprous chloride solution from *M*. For this absorption, not less than half an hour should be allowed; then the cuprous chloride solution may be run out through *O*, and first water and finally dilute solution of caustic potash is admitted through *M*, by means of which all acid vapors may be absorbed. The gas is then run over into *A*, where it is remeasured and the carbon monoxide in the gas is represented by the diminution in volume. Having found the percentages of carbon dioxide, oxygen, "hydrocarbons" and carbon monoxide, nitrogen is estimated by difference, provided no free hydrogen exists, but if there be free hydrogen, the residual gas will be a mixture of both hydrogen and nitrogen, and to determine hydrogen recourse must be had to some form of eudiometer.

An illustration of this tube may be found in Fig. 5. It contains 100 c. c. between the zero mark *X* and the stopcock *y*, and is calibrated between these points into tenths of a cubic centimeter. The top is ground like the top of *B* and may be fitted either to the funnel *M*, or the conical ground mouth of the thick-walled capillary *S*. The platinum wires *t'* are fused into the glass as in ordinary eudiometers, and oxygen and hydrogen may be introduced for explosion through the stopcock *W* on a side capillary. *V* is a bottle which connects with the bottom of the burette by a rubber tubing and is used as the bottles *F* and *R*. The two tubes in the apparatus shown in Fig. 4 are disconnected at 1, and through *S* and a short piece of rubber tubing about 20 c. c. of the residual gas from the previous analysis is drawn into the explosion burette, which prior to this has been entirely filled with water from *V*. Through *W*, a little more than the same volume of oxygen should be introduced and the whole amount of gas accurately measured under atmospheric pressure. By lowering *V*, as great a reduction as possible of the pressure in the burette is made, and a spark is passed through the mixed gases. The water is then passed from *V* into the burette, and after a lapse of fifteen minutes, allowed for the cooling of the gas, a measurement of the volume is taken and the contraction caused by the combination ascertained. Solution of caustic potash is then introduced through the funnel *M*, and after allowing time for the absorption the gas is again measured, and the amount absorbed gives the volume of carbon dioxide due to the explosion. With these data a calculation of the percentages of hydrogen, methane

and nitrogen in the mixture may be made; but a useful check is afforded on the working by estimating the nitrogen as the residue left after absorbing the excess of oxygen by potassium pyrogallate, or after estimation of the excess of oxygen by explosion with hydrogen. If the analysis has been correctly performed, the amount of hydrogen so found and that found by the first explosion should be the same.

Let T equal the volume of gas taken, h, m and n the volumes of hydrogen, methane and nitrogen in it. Then the contraction on explosion will be equal to $1.5\,h + 2m$. The carbon dioxide present will be equal to m, and therefore the quantity of methane in the mixture is immediately ascertained. By substituting this value for m in the contraction equation, the volume of hydrogen formed is shown to be the difference between the amount of contraction and double the amount of carbon dioxide present divided by 1.5; or if C = the contraction and A the carbon dioxide formed by the explosion, then the volume of hydrogen

$$h = \frac{C - 2A}{1.5}, \text{ or } \frac{2C - 4A}{3}$$

The nitrogen is the remainder

$$\text{or } n = T - \frac{2C - 4A}{3} - A = T - \frac{2C}{3} + \frac{A}{3}$$

The percentage composition of the residual gas taken for the explosion is now known, and from the proportion that this residual gas bears to the original gas, the percentages of hydrogen, nitrogen and methane in the original gas are calculated. By performing the analytical work with reasonable rapidity, ordinary temperature variations will not materially affect results, provided the reagents, apparatus and other materials employed have previously been brought to the temperature of the room.

The necessary reagent to be employed in gas analysis, as thus outlined, consists:

First, Of a solution of pyrogallic acid in the proportion of 5 grams of pyrogallic acid dissolved in 15 c. c. of water to which 120 grams of potassium hydrate is added.

Second, The solution of potassium hydrate to consist of one part of potassium hydrate to two parts of water. This solution is decidedly viscous and may be diluted for convenience sake, although absorption is more complete and rapid with the concentrated solution.

[illegible] furnace [illegible] dissolving 103
[illegible] specific grav-
[illegible] on allowing
[illegible] the presence of
[illegible] shape of spiral
[illegible] twenty-four hours
[illegible] condition to use.
[illegible] made by saturating

[illegible] the water which
[illegible] the gas, so that there
[illegible] analysis.
[illegible] has been shown that
[illegible] union of two substances,
[illegible] detailed consideration has
[illegible] embracing the carbon and
[illegible] are the only substances
[illegible] Commonly speaking, little
[illegible] necessary factor, namely,
[illegible] air is of essentially the
[illegible] and as the only expense
[illegible] the needed supply to the
[illegible] combustion, little heed is
[illegible] that universality of com-
[illegible] otherwise to obtain the neces-
[illegible] most expensive and difficult,
[illegible] the essential air supply far
[illegible] affluent.
[illegible] occupying 50 cubic feet absorbs
[illegible] cubic feet, while the products
[illegible] numbers, 12.6 tons by weight
[illegible] from the furnace. Roughly,
[illegible] will consume a ton of coal per
[illegible] 9,000,000 cubic feet would
[illegible] supply, and the ash heap would
[illegible] by 10,500,000 cubic feet. Such
[illegible] a large one, and to compel central
provide necessary storage for gasiform sup-
[illegible] combustion would inflict a burden too

A perusal of the foregoing figures should be a never-failing reminder of that portion of the combustion process usually ignored save as to the proportionment of chimneys and grate bar space, and should arouse a feeling of admiration and satisfaction at the present arrangement of the supply fuel factors, as under the existing circumstances it is only necessary to deliver to the furnace the required amount of air. This operation more properly becomes one of mechanical detail, to be treated in the sections allotted to such part of the subject, and so as an item of discussion under the head of "supplies," disappears from consideration. The necessary lubricants and other minor substances required for central station operation are usually catalogued under the category of supplies, but do not here belong according to the definition assumed in the present treatment of the subject, for the word is restricted to include the material and labor necessary to the production of energy, and as the preceding pages, it is to be trusted, have covered all of the practical forms of supply as employed in central station operating by combustion, it is now necessary to pass to the item of labor.

FLY WHEELS FOR STEAM ENGINES.

BY E. F. WILLIAMS.

Referring to Mr. Taylor's very able contribution * in which he differs from the writer on some points relating to fly wheels for steam engines:

The direction of centrifugal force upon the rim of a wheel in motion is radially from a point within, called the center of rotation. It should not be assumed to act in two opposite directions, as Mr. Taylor considers it. If so, the breaking strain at any point in the rim of a wheel would be the entire centrifugal force divided by 4, as he states it. But to assume this is an error. Without resorting to any formula or consulting any authority, I shall endeavor to show in a few words in what way centrifugal force acts on the rim of a wheel and how the rim resists the strain tending to break it. If you take a bar, put the end of it under a stone and place a fulcrum under the bar at one-quarter the distance from the stone to the hand at the other end of the bar, and press downward, you will find that one pound at the hand will balance three pounds at the stone. This is true, for the reason that the longer end of the lever is three times the shorter. The purchase being as 3 to 1, if you should press down sufficiently on the lever to raise the stone, the hand would move downward *three times as fast* as the stone would move upward. This illustrates the law that governs mechanical purchase throughout the universe. One pound through two feet, for example, equals two pounds through one foot, and so on. When, therefore, a breaking strain is brought on any form of material, its purchase equals its *velocity* relative to that of the part broken, assuming it to break.

Now, apply this law to the rim of a wheel under centrifugal force. As I have said, the force acts in all directions (in the plane of rotation). It is the same in quantity as though the entire mass of the rim was centered at a point as it is when you whirl an apple round the hand by a string. In the wheel the

* "Some Notes on Fly Wheels," by Irving A. Taylor. ELECTRICAL ENGINEERING, November, 1896.

weight is distributed equally all around the circumference of the circle. The force, therefore, is distributed in the same manner and acts from the center. Assume the wheel rim to break: the two broken ends would move apart with a velocity of 3.1416 times that of the enlargement of the circle radially. The former is the resisting and the latter the breaking velocity. The former is, therefore, 3.1416 times the latter. At the point of breaking the breaking force is divided into two equal parts. One-half of the resultant centrifugal force is exerted one way and one-half the other, and either must be sufficient to cause the break. The purchase of rim over centrifugal force being 3.1416 to 1, we have the following rule: To obtain the breaking strain, divide the entire centrifugal force by (3.1416 × 2 =) 6.2832.

As to centrifugal force being the same at given periphery velocities in all diameters, I consider it hardly necessary to explain this in detail. We know this force varies as the square of the revolutions and directly as the diameter of the circles of revolution. Assume, first, two wheels the same diameter, and rim section at different velocities. Their centrifugal forces will be as the squares of their rates of rotation. Their periphery velocities will vary only as the rates of rotation. The centrifugal force, therefore, does not vary as the speed, as Mr. Taylor asserts.

His criticisms of that portion of my article referred to on page 278 shows considerable ingenuity. I did not think, and do not now see, how my statements — plain as they appeared to me — could have been construed in such a way. I have no changes to offer in my former wording. If a wheel should be speeded from 6,000 feet a minute to 12,000 feet per minute, its efficiency would certainly be doubled. That is to say, it would give out twice the energy for any given per cent of retardation, and compared with the wheel force the dynamo resistance becomes one-half, as stated in my article.

As to the rotative effect of the reciprocating parts, as stated in my former article, the actual weights of wheels in most all situations are so much in excess of that required to neutralize the irregularities in the crank thrusts that the angularity of connecting rods, the inertia of the reciprocating parts and the distribution of steam pressures need not be considered. In our practice, when small wheels are desirable, as it sometimes occurs for structural reasons, we secure the required uniformity of motion by the

introduction of more cranks. We use two 10-foot wheels, for example, about 12-inch by 14-inch section of rim, on our 1,200 horse-power triple expansion, and three-cylinder compound engine, at one hundred revolutions per minute. You might say these wheels were light, perhaps. The motion, however, is highly satisfactory in actual service. In some cases, which are rare, crank thrusts should be considered. It would take a very long article, however, to explain this matter. The writer went into the subject some years ago, and furnished the *American Machinist* with a series of articles on "Inertia in the Reciprocating Parts of Steam Engines" (in which the subject was treated almost wholly arithmetically) and invented an instrument for measuring this force. Cornell University has one of these instruments. It has been the writer's custom to give matters of this nature a careful study and establish some simple rule or formula that will cover the subject as far as its application in my practice goes, to the best of my judgment.

We are frequently required to furnish complete specifications on very short notice. Our processes, therefore, for arriving at the various points to be embodied (there are a great many of them) must be short and direct, and in a large measure general.

In conclusion, would say that the nature of the governor — its ability to respond quickly to any change in motion — is a very large factor in the performance of the steam engine and should enter into all estimates on the fly wheels.

THE TELEPHONE EXCHANGE.

BY R. R. BOWKER.

The telephone exchange is an application of the "permutation" which the schoolboy studies in his arithmetic. "Central" occupies a large room, containing a continuous "switchboard," along which from fifty to one hundred and fifty operators sit. Each girl has to attend one of three "divisions" of a "section" of this board, all three being within easy reach, each division representing from fifty to one hundred and fifty subscribers, according to the frequency of use. Her head is bound with what seems a Grecian fillet, but which proves to be a band for the receiving instrument, which she wears constantly at her ears. Each subscriber has his own wire, connected (through stranded cables, led underground, in subway systems such as that in New York) directly with the "drop" on his division of the switchboard. For long-distance transmission, and in cities where there is great electrical disturbance underground, the earth cannot well be used for return, and there is a complete circuit of two wires between each telephone and "Central." When a subscriber makes a call, he uses the line as a telegraph wire, energizing it from the magneto-electric machine, which he turns by the handle; by thus charging the circuit he releases the "drop" which bears his number on the telephone switchboard, and also proves to himself by the ringing of his bell that he has completed the circuit and given the desired signal. In the great room of the central office, where the talk of a hundred girls seems a buzz of quiet whispering, the silent "drop" tells the whole story, and the exasperated subscriber who is ringing his bell furiously troubles only himself — a fact quite impossible to impress upon the average office-boy. The telephone girl now puts a "plug" in the "jack" at which the subscriber's wire terminates, restoring the "drop" automatically, and asks the subscriber to name the number he desires. Each subscriber must be instantly connected with any other subscriber of the same exchange, or with a "trunk line" leading to some other exchange, and thus to the

introduction of mo[illegible]
example, about 12-in. [illegible]
horse-power triple [illegible]
engine, at one hundred re[illegible]
these wheels were [illegible]
satisfactory in [illegible]
crank thrusts [illegible]
article, however, [illegible]
the subject so [illegible]
with a series of [illegible]
Steam Engines [illegible]
arithmetically [illegible]
force. Corne[illegible]
been the write[illegible]
study and [illegible]
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best of my [illegible]
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In co[illegible]
its ability [illegible]
large fact[illegible]
enter [illegible]

RECENT PUBLICATIONS.

THE PRINCIPLES OF THE TRANSFORMER. By Frederick Bedell, Ph.D., Assistant Professor of Physics in Cornell University. New York: The Macmillan Company, 1896. 416 pages, 5½ by 8½; cloth; price $3.25.

Bedell and Crehore's book on alternating currents, which justly took such a prominent position in alternating current literature in this country as well as abroad, and many very instructive papers written by the same authors on the same subject, have placed a known value on all that bears the names of Bedell and Crehore. The present book, suggested by Doctor Crehore and the author, but worked out by the latter, is written entirely in the spirit of the earlier work on alternating currents, and, for that matter, could have been made an additional volume to the same, as it is an extension of it, referring especially to the transformer. After the introduction of the transformer in its manifold rôles, all notations and conventions employed in the book are tabulated in a very practical manner. The induction and the magnetizing force are noted by heavy type, while afterward vectors are noted by ordinary type; but heavy type being once introduced, why not mark vectors also in heavy type for distinction? The theoretical discussion of the transformer and its circuits are clearly written. The contents of the chapters on magnetic circuit, alternating current, transformer diagram, analytical theory of the transformer, constant current and constant potential transformer will be familiar to anyone who has kept in touch with the progress in alternating current theory during the last few years, but herein it is all collected and developed in such a satisfactory manner. In the eleventh chapter the author takes up the analytical treatment of current flow in two mutually related circuits, and develops the differential equations involved thereby. This chapter, as well as the next following ones, up to Chapter XV, are somewhat trying, perhaps, on the non-mathematical student, but they contain very interesting studies and the explanation is so lucid that they should not offer any great obstacles. The [illegible] reciprocal vectors in the study of transformer resonance deserves [illegible]al attention. With Chapter XV begins the practical part of the [illegible] All there is must be given credit for usefulness, but there is not [illegible] design and construction was entered into at all, they [illegible]ven a fair share. The transformers mentioned repre-[illegible]ngent of the great variety in daily use; multiphase [illegible]ion motors, those restless transformers, are not [illegible] be done in a construction book. Also tests and [illegible]nsformers in actual use would be desirable, as well [illegible]erefrom, as the annual efficiency is essential to an [illegible] short, the author would put the whole electrical [illegible]on if he would work out the transformer practice [illegible]nner as the theory is treated. There is a demand [illegible] and the labor involved in composing it, though not [illegible]t in such a measure as theoretical investigation, [illegible]knowledgment of the readers.

F. J. DOMMERQUE.

[illegible]

[illegible] The author has seen to [illegible] with the modern methods of instruction. [illegible] a treatise in brevity, or rather a guide [illegible] Professor Lattey's ability and wide experience [illegible] a most judicious selection and an elementary treatment of his [illegible] will [illegible] some of its burdensomeness. The nature of heat is first considered, Joule's and Joule's experiments proving heat to be the energy of motion are briefly described. Radiant heat is then considered, followed by temperature and its measurement, expansion, measurement of the quantity of heat, fusion and vaporization. Chapters devoted to the consideration of heat radiation and absorption contain interesting tables of the properties of various substances and the development of simple formulæ for the transmission of heat, rate of cooling, etc. Under thermodynamics Joule's experiments are first considered, then Kelvin's correspondence by Joule's equivalent. The considerations of isothermal and adiabatic lines of expansion leads to the Carnot cycle, a practical illustration being given. The treatment of heat concludes with a chapter on the [illegible] of gases. It will be seen that the course outlined may be made as complete as desired, and to this end frequent notes refer one to the standard works of Tait, Maxwell, Tyndall, Clausius, Preston and Stewart. About [illegible] pages are devoted to the subject of electricity and magnetism, the first chapters treating of electric charges, electrification, electric potential, capacity and condensers. Primary cells and electrolysis are considered quite thoroughly, and as an illustration of the modern views the author has incorporated one might call attention to the fact that the theory given of the production of a current in the voltaic cells is the very recent one of Ostwald, based on the earlier work of Vant Hoff, on solution, tension and osmotic pressure. The energy available in the cell is shown to depend upon the heat evolved by the combination, diminished by that absorbed in producing depolarization or its equivalent. This treatment being general enough to avoid the contentions suggested by Helmholtz regarding the thermal energy actually available. The author again avoids contention in considering the storage cell by very properly dismissing the chemical reactions, on the ground that they are to some extent undetermined. An interesting chapter treats of thermal relations, including electric heating, welding and the thermo-electric effects, including the thermo pile, etc. Under magnetic induction are considered electric discharges in high vacua and cathode rays, mention being made of the Röntgen effects. The work concludes with a chapter on electric oscillations and waves. The period of oscillation and resonance being briefly treated, followed by Maxwell's electro-magnet theory of light and Hertz' researches demonstrating Maxwell's theory.

L. L. SUMMERS.

SYNOPSIS OF CURRENT ELECTRICAL LITERATURE. 1895. By Max Osterberg. New York: D. Van Nostrand & Company, 1896. 143 pages, 7 by 10; price, $1.

Electrical progress is so rapid, and electrical development, ramifying through every department of daily life, entwines itself so completely through every section of modern life, that it is impossible for even the most voracious bookworm to assimilate the necessary electrical knowledge that is daily presented to his palate. But it is equally essential to the practicing engineer to be able at pleasure to place his hand upon information bearing on any part of the art in which he may be interested. Mr. Osterberg has endeavored to set such a catalogue of electrical news within reach of all as will enable those desirous of information, upon current topics electrical, to turn immediately to the source of the latest information upon the point desired. Many systems of digest have been attempted and some valuable ones are now in use, but Mr. Osterberg's work appears to be more full and complete than those that are commonly at command. The book is alphabetically arranged, separate sections being devoted to the principal electrical subjects, the paragraphs in each giving a short résumé of the article referred to. The references are clear and italicized for perspicuity, and the only criticism that can be passed upon work of this kind is that it inevitably becomes out of date ere it falls into the hands of the purchaser.

A. V. ABBOTT, C. E.

MISCELLANEOUS PAPERS. By Heinrich Hertz, with an introduction by Prof. Philipp Lenard. New York: The Macmillan Company, 1896. 340 pages, 6 by 9; price $3.25.

Miscellaneous Papers form the first volume of Hertz's collected works, which are edited by Dr. Philipp Lenard. The second volume has already been translated into English and published as "Electric Waves." The present volume is designed to accompany the previous volume, and is the same in size and binding. Dr. Lenard as a pupil of Hertz's had every opportunity of becoming familiar with Hertz's work and has himself achieved distinction in research outlined by Hertz, as he may be looked upon as the father of Röntgen phenomena. The introduction to the present papers contains interesting matter to the biographically inclined person and gives one an insight into the earlier life of Hertz — a number of letters written to his father tell the story of earlier trials and of the decision to adopt a life of research and study rather than the more directly remunerative profession of an engineer, which had been the earlier intention. The preparation of the first paper, that upon "Self-Induction," the courtesies extended to the struggling young scientist by Von Helmholtz, the success achieved, but above all the distinction which was to lead rapidly to wider fields and greater opportunities, are told in a pleasing and interesting way. The papers include that upon "Self-Induction," the first important research of Hertz, followed by the paper on "Induction in Rotating Spheres," which won for him his doctor's degree. His paper on evaporation of liquids, and a brief description of his hygrometer, are given, also some papers on the electric discharge and experiments with the cathode discharge. Some of his clear, lucid reasoning upon these subjects is most interesting in view of the results since accomplished. His belief that the cathode ray must be regarded as a phenomenon quite independent of the

actual discharge and no more connected with it than the light which radiates from the discharge, foreshadowed the Röntgen application, particularly as Hertz pointed out that the penetration through thin metal sheets, etc., would be difficult to explain otherwise. The translator's work has been particularly well done, and the student of original papers will find the work a most desirable addition to the library. L. L. SUMMERS.

BOOKS RECEIVED AND GIVEN OUT FOR REVIEW.

AMERICAN ELECTRICAL CASES. Being a collection of all the important cases (excepting patent cases) decided in the State and Federal Courts of the United States, from 1873, on subjects relating to the Telegraph, the Telephone, Electric Light and Power, and Other Practical Uses of Electricity, with annotations. Edited by William W. Morrill, author of "Competency and Privilege of Witnesses," "City Negligence," etc. Vol. V, 970 pages. Albany, New York: Matthew Bender, Law Publisher, 511–513 Broadway, 1896. 6½ by 9½; price, $6 a volume.

A PRACTICAL TREATISE ON THE OTTO CYCLE GAS ENGINE. By William Norris. New York: Longmans, Green & Co., 1896. 260 pages, 6 by 9; 207 illustrations.

THE NATIONAL ELECTRICAL CODE. An analysis and explanation of the Underwriters' Electrical Code intelligible to non-experts. By Pierce and Richardson. Chicago: Charles A. Hewitt, 510 Royal building, 1896. 222 pages, 4½ by 7; leather; price $2.

TRANSFORMERS FOR SINGLE AND MULTIPHASE CURRENTS. A treatise on their theory, construction and use. By Gisbert Kapp. New York: The Macmillan Company, 66 Fifth avenue, 1896. 241 pages, 5 by 8; 133 illustrations; price $1.75.

HISTORY AND STATISTICS OF CHICAGO STREET RAILWAY CORPORATIONS. Chicago: The Economist Publishing Company, 1896. 96 pages, 10 by 13; 20 maps; price $1.

ALTERNATING CURRENTS AND ALTERNATING CURRENT MACHINERY. Being Volume II of the text-book on "Electro-Magnetism and the Construction of Dynamos." By Dugnald C. Jackson, C.E., and John Price Jackson, M.E. New York: The Macmillan Company, 1896. 729 pages, 5½ by 8; 334 illustrations; price $3.50.

LEHRBUCH DER EXPERIMENTALPHYSIK. Von Adolph Wüllner. Erster Band: Allgemeine Physik und Akustik. 1016 pages, 6 by 9½; 321 illustrations; paper, uncut; price 12 marks. Zweiter Band: Die Lehre von der Wärme, 1896. 935 pages, 6 by 9½; 131 illustrations; paper, uncut; price 12 marks. Leipsic: B. G. Teubner.

THE ELEMENTS OF PHYSICS. A college text-book. By Edward L. Nichols and William S. Franklin. In three volumes. Vol. II, "Electricity and Magnetism." New York: The Macmillan Company, 1896. 272 pages, 6 by 9; 371 illustrations; price $1.50.

LES TRAMWAYS ÉLECTRIQUES. Par Henri Maréchal. Paris: Baudry et Cie, Rue des Saints-Pères, 15, 1897. 203 pages, 6 by 9; price 7 francs 50 centimes.

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